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(FOUO 6/79)

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TRANSLATIONS ON USSR RESOURCES

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CONTENTS PAGE

FUELS AND RELATED EQUIPMENT

EQUIPMENT FOR REMOVING WATER AND SALT FROM OIL

Moscow PROMYSLOVAYA PODGOTOVKA NEFTI in Russian 1977 pp 72-109

[Chapter III from the book "Promyslovaya Podgotovka Nefti, Nedra]

[Text] Hydrodynamic Coalescers (Drop Formers)

The hydrodynamic drop formers are designed to rupture the armoring shells or stratal water globules, the enlargement of the globules and the stratification of the stream into oil and water before standing of the emulsion. The consolidation of the drops takes place directly in the oil flow, on the walls of the drop formers or on the built-in hydrophilic elements under the effect of turbulent pulsations.

The volumetric and tubular drop formers are distinguished (see Figure 29). The volumetric drop formers are hollow or have rigid hydrophilic elements. In the hollow volumetric drop formers, the collision and coalesence of the globules are achieved by introduction of the emulsion into the volume of the equipment through nozzles directed at diffe·ent angles to each other or turbulization of the flow inside the equipmer by mechanical or other means. For intensification of the processes of lescence of the globules, the additional coalescent elements have been int uced into the emulsion flow, for example, in the form of drops of drainage water which are easily removed from the flow with subsequent standing, and the problems of their regeneration are not created (in contrast to shavings, glass, and so on). The version of intense coalescence of the drops by turbulization of the emulsion in the volume of the drainage water (the hydrophilic medium) by mechanical means is possible. The application of volumetric drop formers with developed hydrophilic coalescing surface made up of corrugated, platy or tubular elements operating, in contrast to the other materials (balls, shavings) in the self-cleaning mode is prospective.

The tubular drop formers are structurally made of bundles of tubes of calculated length and diameter. The linear and sectional tubular drop formers are distinguished. The linear drop formers are made of tubes of identical diameter. In the sectional drop formers the tube diameter increases from section to section [94, 111, 163, 191]. This permits successive enlargement of the drops to the given sizes. Just as in the volumetric and in the sectional drop formers, the application of a moving hydrophilic coalescing medium is possible in the form of drops of drainage water, centrifugal swirlers of the flow which throw the globules against the walls of the drop formers and built-in rigid plate or tubular coalescing elements operating in the self-purification mode.

The advantages of the volumetric hydrodynamic drop formers are the following: high specific output capacity, small size, low metal consumption, the possibility of their use as autonomous elements or elements built into a settling tank and also the possibility of the application in projects with small process sites and under especially crowded conditions. The advantages of the linear and sectional tubular drop formers are the following: the possibility of their use simultaneously both as coalescing units and as communication lines between the heat exchange and settling equipment, the settling tanks of the first and successive stages, the settling tanks and the commercial tank parks, and so on. The advantages of the hydrodynamic drop formers over the electrical coalescers are the following: the possibility of calculating the enlargement of the drops to a given diameter, the possibility of control (regulation) of the coalescence process by connection and disconnection of the required number of sections, the low cost and metal consumption, the low consumption of electric power, the simplicity and safety of servicing, and operating reliability.

Breakdown of the Emulsion in the Drop Formers

The linear drop formers, their peculiarities and nature of breakdown of the emulsions in them have been investigated in the literature [85, 107, 147, 168]. The first experimental model of the sectional drop former was investigated on the Bablinskaya thermochemical units and subsequently on the Biryuchevskaya thermochemical units of the Tatneft' Association. The drop former had three sections made of thermally insulated tubes located on the lower supports and the horizontal plane. Their diameter increases from section to section in the direction of movement of the treated emulsion. The first section is designed, just as the ordinary linear drop former, for breakdown of the armoring shells of the globules of stratal water and their consolidation with high parameters of the turbulent flow both in the volume of the treated emulsion and on the walls of the tubes; the second section is for coalescence of drops to larger dimensions with lower values of the Reynolds parameters; the third (last) section was designed for investigation of the theoretical possibility of stratification of the flow into oil and water in the pipeline for values of the Reynolds parameter above critical and holding time of the oil in the equipment less than 10 minutes.

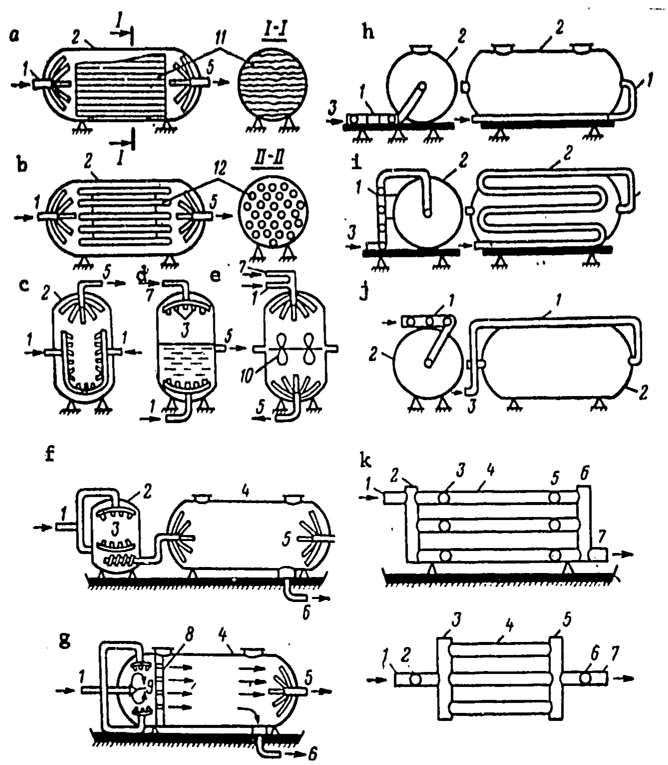


Figure 29. Schematic Diagrams of Hydrodynamic Drop Formers and Tubular Settling Tanks;
Volumetric Drop Formers (a, b, c, d, e, f, g):
1--Emulsion input; 2--Housing of the drop formers; 3--Nozzles; 4--Housing of the settling tanks; 5--Terminal distributing liquid input and output; 6--Water discharge; 7--Drainage water input; 8--Distributing baffle; 9--Settling tank; 10--Mixer; 11--Sheet coalescing elements; 12--Tubular coalescing elements.
Tubular Drop Formers (h, i, j):
1--Tubular drop former with settling tank; 2--Settling tank; 3--Emulsion input.
Tubular Settling Tank Module (k):
1--Emulsion input; 2--Vertical distributor; 3--Horizontal distributor; 4--Sections of the drop former; 5--Horizontal header; 6--Vertical header; 7--Emulsion output.

The studies of the nature of the breakdown of the emulsion in the drop former of the Biryuchevskaya thermochemical device demonstrated (see Figure 30) that standing of the oil taken at a distance of 20 meters from the beginning of the first section of the drop former (the tube diameter 250 mm, R= 53,000, q = 35 g/ton, t = 40° C, W = 10-15 percent, movement time 20 seconds) ends on after 1.5 hours. The increase in standing time does not in practice lead to further separation of the water. The residual water content in the oil is on the average 3.58 percent. This indicates that in the initial section of the drop former the finely dispersed part of the stratal water globules remains undisturbed, and the emulsion is characterized by a finely disperse structure. Increasing the emulsion processing time in the drop former to 2.5 minutes (sampling point at a distance of 200 meters, section diameter 250 mm) led to significant reduction of the water content in the oil while standing (the residual water content in the oil in this case was on the average 1.17 percent). A further increase in the emulsion processing time in the drop former to 3.5 minutes (sampling at a distance of 500 meters, section diameter 250 mm) led to a still greater increase in depth of destruction of the emulsion. After the oil sample at this point stands for an hour, the residual water content in it is 0.53 percent which is 6 times less than the water content in the oil taken from the initial section of the drop former (Figure 30, a) with a standing of 1.5 hours.

Attention is attracted to the uniformity of the emulsion structure with respect to the cross-section of the first section of the drop former. The water content in the oil and the depth of dehydration during standing of the emulsion samples taken in different cross-sections are in practice identical. Still more efficient consolidation of the drops of water free of the shells in the first section was achieved in the second section of the drop former. As a result of sharp consolidation of the water drops during movement of the emulsion through this section for 1.5 minutes, the time required for the oil to stand was reduced to 30 minutes. Simultaneously, the residual water content in the oil was cut in half (after 30 minutes of standing it was 0.3 percent, which characterizes the oil as deeply dehydrated).

Thus, inclusion of the second section of the drop former with processing of the emulsion in it for 1.5 minutes makes it possible to cut the standing time in half with simultaneous improvement of the quality of the oil. It should be added that a tendency of the emulsion towards stratification has been detected in the second section. This is manifested in increased water content in the lower sample, faster and deeper suppression of the water from the oil during standing.

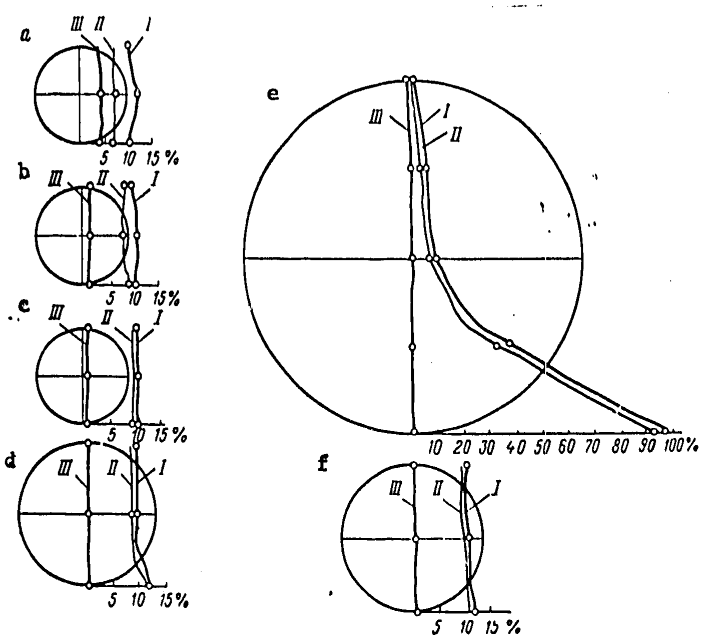


Figure 30. Variation in Degree of Dehydration of the Water Samples Taken along the Length of the Drop Former Characterized by Different Flow Parameters.
a--Re = 53,000, t = 20 seconds, D = 250 mm, v = 2.6 m/sec;
b--Re = 53,000, t = 2.5 minutes, D = 250 mm, v = 2.6 m/sec;
c--Re = 53,000, t = 3.5 minutes, D = 250 mm, v = 2.6 m/sec;
d--Re = 36,000, t = 5 minutes, D = 350 mm, v = 1.3 m/sec;
e--Re = 9,100, t = 5 minutes 50 seconds, D = 1400 mm, v = 0.08 m/sec; f--Re = 36,000, t = 6 minutes, D = 350 mm, v = 1.3 m/sec.
a, b, c, d, e, f--Sample taking points; t--Time for the emulsion to move from the beginning of the drop former; D--Diameter of the drop former; I--Water content in the emulsions, %; 2--Amount of water released, %; 3--Residual water content, %.

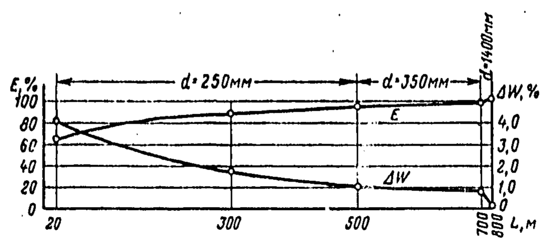


Figure 31. Variation of Degree of Dehydration (E) and Residual Water Content in the Oil Samples (Δ W) with Respect to Length of the Sectional Drop Former L with an Emulsion Consumption of 460 m^3/hr.

In order to estimate the possibility of stratification of the emulsion flow into oil and water in the settling tanks with minimum folding time of the oil, a 7 cubic meter tank was installed as the third section of the drop former, the design of which made it possible to discharge the separated water from the lower section of it. The flow turbulence was characterized by a Reynolds number of 8800. The oil samples taken in this section with respect to the flow cross-section demonstrated that its stratification during standing in less than 2 minutes in the equipment is impossible for the given degree of turbulence. The first signs of stratification were detected for values of $Re \approx 5,000$ and confinement time of the oil in the apparatus of 2 minutes.

It is obvious that these two parameters are mutually compensated within defined limits, and increasing the time the oil is in the apparatus to 10 to 15 minutes permits discharge of the stratal water for large values of the Reynolds numbers.

The dependence of the depth of dehydration of the oil on the length and diameter of the tubes of the sectional drop former is illustrated in Figure 31. From the graphs it is obvious that with an increase in length of the drop former with simultaneous stepped increase in tube diameter from section to section in the direction of motion of the emulsion, the efficiency of treating it increases, which, in the final analysis, makes it possible to obtain in practice water-free oil from the settling tanks.

From Figure 31 it follows that if the length of the first section of the experimental drop former turned out to be twice as high as necessary it can be decreased. Connection of the drop former to a 200 cubic meter settling tank produced oil with a residual water content of 0.1-0.2 percent for an output capacity of 460 m^3/hour.

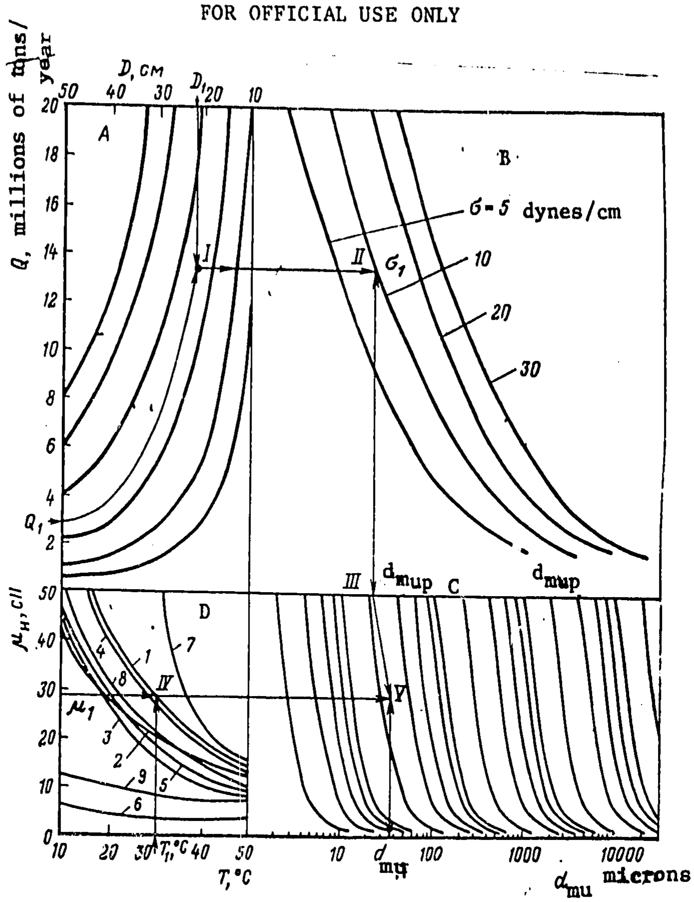


Figure 32. Nomogram for Calculating the Diameter of the Mass Exchange Section of a Drop Former, the Drop Size and Other Parameters: Q--Output capacity; D--Diameter of the drop former; d_{mup} is the maximum stable diameter of the globules (intermediate value); d_{mu} is the maximum stable diameter of the globules; μ is the viscosity of the dispersion medium (oil). Oil: 1--Romashka (coal-bearing); 2--Bavlinskaya (coal-bearing); 3--Romashka (devonskaya); 4--Zapadnosurgutskaya; 5--Ust'-Balikskaya; 6--Samotlorskaya; 7--Mangyshlakskaya; 8--Arlanskaya; 9--Krasnoyarskaya

Calculating Hydrodynamic Drop Formers

For proper selection of the equipment ensuring effective destruction of the emulsion by the thermochemical method under the most favorable hydrodynamic conditions, it is very important to have definite methods of calculating it. In connection with the rapid increase in extraction of dehydrated oil and the necessity for building a large number of new oil preparation units, it is necessary to learn how to calculate the parameters of such units as the sectional drop formers. The application will permit the output capacity of the settling tanks to be increased in the stages of removing water and salt from the oil, the number of settling tanks on site and their metal consumption to be decreased, the size of the process areas and number of monitoring and service points to be decreased, and the stability of the oil preparation processes to be improved. In this case the processes of removing the water and salt from the oil can take place at low temperature, with low consumption of the emulsifiers and fresh wash water. The construction time for the units and the cost of preparing the oil are reduced. The productivity of labor is improved.

In the modern oil preparation process in the desalination and dehydration stages, broad use is made of mass exchange and coalescence sections, each of which is specially designed.

Determination of the Parameters of the Drop Formers in the Dehydration Stage

The supply of the reagent to the globules of the stratal water and the destruction of the protective shells on their surface in the mixing units of existing structures (valves, gates, nozzles, and so) are not efficient for the following reaons:

Insufficient mixing time (fractions of seconds, seconds);

Extraordinary fractionation of the drops (to 1-2 microns);

Impossibility of monitoring the process.

The mass exchange processes, as a rule, are realized outside these units in the lines between units, and they take place spontaneously. Their efficiency is determined by the random parameters of motion of the emulsion. Under these conditions a significant number of drops with unruptured protective shells reach the settling tank, lowering its operating efficiency. The mass exchange section of the drop former is designed for effective mass exchange between the globules of stratal water and the drops of water containing the emulsifier reagent (with probability of 0.999 and more) under conditions ensuring the possibility of existence of drops of a given size in the flow.

In contrast to the usual type mixers, in the mass exchange section of the drop former, the delivery of the reagent to the globules of stratal water and the destruction of the protective shells are realized under the conditions of interfering processes of fractionation and coalescence of the drops, the given size of which is controlled by the flow regime characteristics. This permits exclusion of the possibility of redispersion of the drops and ensures rapid consolidation of them in the coalescence section. Only the results of the collisions of the drops within the oil are taken into account in the calculations. The mass exchange processes which take place on the walls of the sections, which play the role of inverting screens, are not taken into account. This makes it possible to obtain a reliability coefficient for the calculated data on the order of 1.7 [153]. In order to ensure completeness of the mass exchange process in a technologically acceptable time, an effort is made to fractionate the drops in the flow to defined dimensions selected as a function of the water content of the oil to be treated. Beginning with the conditions of equality of the distances between drops in the emulsions with different water content it is recommended that the following calculated values of the diameters of the water drops in the oil treated in the mass exchange section be used:

W, %..................1	5	10	15	20	30
d, microns............5	10	22	27	36	68

These values are taken into account when determining the diameter and the length of the mass exchange section.

The diameter of the mass-exchange section D is determined by the given or known parameters Q, μ_H, ρ_H, d_{mean}, σ, using the nomogram in Figure 32 or from the expression:

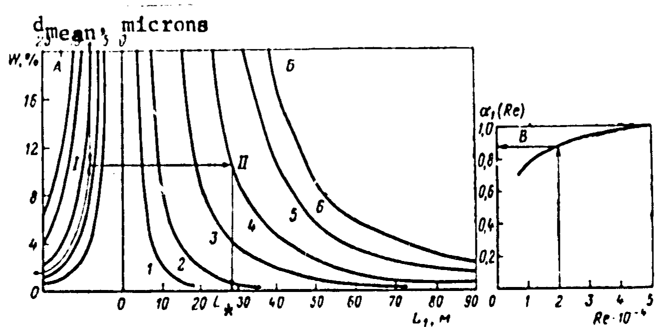
$$D=\left\{\frac{43.3\sigma^{1.5}\left[1-0.7\left(\frac{\mu_B u}{\sigma}\right)^{0.7}\right]}{d_{cp}^{*}u^{2.5}\mu_H^{0.5}\rho_H}\right\}^{10}, \qquad (62)$$

*mean

where σ is the surface tension at the oil-water interf. ., dynes/cm; μ_B and μ_H are the dynamic viscosity of the water and oil respectively, poise; d_{mean} is the average diameter of the drops, cm; u is the mean volumetric flow rate, cm^3/sec; ρ_H is the density of the oil, g/cm^3.

The value of σ is determined experimentally the known procedure on a stalagmometer after dehydration of the oil at the process temperature for the adopted flow rate of the reagent under actual conditions. The determination of the diameter of the mass-exchange section using the nomogram in Figure 32 is made as follows. The intersection point of the horizontal and perpendicular drawn from the corresponding given values in the C quadrant is found by the known values of μ_H in the D quadrant. From the point V obtained, moving parallel to the directing curves, the intermediate axis d_{mup} is reached, and a perpendicular is drawn from it to the intersection with one of the curves corresponding to the value of σ in the V quadrant (point II). Drawing a horizontal line from the point II to the left into the quadrant A to the intersection with the curve corresponding to the given value of the output capacity Q, the point I is obtained. The perpendicular from this point to the D axis gives the desired value of the mass exchange section diameter.

In the case of noncoincidence of the value of the diameter with the standard value, the next highest value of the standard tube size is assumed the curves in quadrant B correspond to the values of the surface tension coefficient of 5, 10, 20 and 30 dynes/cm. Curves 1-9 of quadrant D express the viscosity-temperature function for the oils of different oil-extracting parts of the country. For example, for Q_1 = 3 millions/year, μ_H = 30 centipoise, d_{mean} = 35 microns and σ = dynes/cm the diameter of the mass exchange section turns out to be equal to 22 cm (the reckoning scheme as noted by the arrows on the nomogram).



*$L_{1\ int}$ = intermediate value of line length.

Figure 33. Nomogram for Determining the Length of the Mass Exchange of the Drop Former or the Process Line:
W-- Water content; d_{mean}--Average size of the globules;
$L_{1\ int}$ is the intermediate value of the line length,
α_1 is the correction factor for the motion regimen. The point of introduction of the demulsifer into the flow:
1--On group units; 2--On the head sections of the collecting lines; 3--In the terminal stages of separation; 4--For reception of raw material pumps; 5--Before the pumps; 6--At the entrance to the mass exchange section

The calculated length of the mass exchange section can be determined by the nomogram in Figure 33 or by the formula [151]

$$L_1 = \frac{\ln\left[\left(\frac{W-W_{p0}}{W_{p0}}\right)\Big/\left(\frac{W-W_p}{W_p}\right)\right]}{\frac{K_1}{d_{cp}}\sqrt{W\left(\frac{\pi D\nu}{4Q}\right)^{0.25}}} + 20D, \qquad (63)$$

where W is the flooding of the oil (in relative units); W_{p0} is the amount of introduced reagent solution (in relative units); W_p is the amount of water in the oil enriched by the reagent as a result of the mass-exchange processes during movement in the section (usually given as 0.999); K_1 is the collision efficiency constant; d_{mean} is the mean drop diameter, cm; D is the diameter of the mass exchange section, cm; ν is the kinematic viscosity of the oil, stokes; Q is the flow rate of the treated oil, cm^3/ sec.

The mean drop size is selected as a function of the water content of the treated oil: with an increase in water content the drop diameter is assumed to be large, which subsequently facilitates the operation of the coalescing section. The length of the section is determined with the help of the nomogram (see Figure 33) in the following way. The given value of W is found on the flooding axis, and a curve is drawn from it parallel to the lines with equal flooding to the intersection with the perpendicular dropped from the selected value d_{mean} (point I). Drawing a horizontal line from the point obtained to the right to the intersection with the selected collision effectiveness curve, point II is obtained. Dropping a perpendicular from it to the L_1 axis, the intermediate value of the length of the mass exchange $L_{1\ int}$ is reckoned. The total length of the section is determined considering the coefficient of the motion regimen α_1 and the section for establishment of the flow $\Delta L = 20$ D. The value of α_1 is determined using the auxiliary graph in Figure 33 by the known value of the Reynolds number which is calculated by the formula

$$Re = \frac{4Q}{\pi D \nu_e},$$

where ν_e is the kinematic viscosity of the emulsion, stokes.

$$L_1 = \alpha_1 L_{1\text{пр}} + 20D.$$

Depending on the reagent feed point in the process system for preparation of the oil various curves are used for the collision effectiveness constants. In particular, when feeding the reagent on the group devices curve 1 is used; on the head sections of the collecting lines, curve 2, in the terminal separation stages, curve 3; for the crude oil material pump intake cutve 4; before the pumping elements curve 5; directly before the mass exchange section curve 6. For example, for d_{mean} = 10 microns, W = 1.5 percent, D = 22 cm (the reagent is sent to the crude oil material pump input), and Q=2 million tons/year by the nomogram in Figure 33 in the intermediate value of the length of the mass exchange section $L_{1\ int}$ turns out to be 28 meters. For the calculated value of Re = 20,000, α_1 = 0.84 meters, $\alpha_1 L_{1\ int}$ = 33.8 meters. For D = 22 cm the value of ΔL_1 = 4.4 meters. The total length of the mass exchange section is defined as

$$L_1 = \alpha_1 L_{1\text{пр}} + \Delta L_1 = 23{,}5 + 4{,}4 = 27{,}9 \text{ м}.$$

Determination of the Parameters of the Coalescing Section

The output capacity of the settling equipment increases proportionally to the square of the diameter of the stratal water globules. Therefore before arrival of the emulsion in the settling units it is necessary to see that the globules free of the protective shells coalesce to the largest dimensions possible. The basic parameters limiting the possibility of unlimited increase in dimensions of the water globules are Q, D, μ_H, σ [154, 207, 217, 222]. The calculation of the coalescing section is realized considering the hydrodynamic parameters of the flow ensuring the possibility of obtaining the largest size drops with the exception of the possibility of premature stratification of the emulsion as a result of gravitational settling. This ensures the possibility of prolonged interaction of all the drops in it, constriction of the spectrum of the drop diameters and maximum possible approach of them to the optimal value. In order to prevent stratification of the emulsion in the coalescing section, the turbulent regime is maintained on the level where the vertical component of the velocity pulsations will exceed the rate of gravitational sedimentation of the water drops. This condition is also assumed as the initial condition limiting the consolidation process.

The maximum size of the water drops not subject to fractionation in the turbulent flow of oil and the size of the drops which have been suspended in this flow are defined for various values of Q, μ_H using the nomogram in Figure 25 constructed for fixed values of σ = 10 dynes/cm in the coordinate d = f (D). For the given value of Q and μ_H with respect to the intersection of the curves of maximum drop size (1-7) with the curves of the drop diameters (1'-7') which can be suspended under the given conditions, the position of point I on the graph is defined. Dropping the perpendicular to the axis of the tube diameter, its value of D_{1im} is defined. The effect of the values of the surface tension differing from 10 dynes/cm is taken into account using the correction factor K_σ which is defined by the formula

$$K_\sigma = \left(\frac{\sigma}{10}\right)^{\frac{13}{2}},$$

where σ is the actual magnitude of the surface tension, dynes/cm.

The final diameter of the coalescing section is written as $D = D_{mim}K_\sigma$, and the least size with respect to the standard is assumed. The graphs of the nomogram in Figure 25a-e correspond to the oil viscosity of 50, 30, 20, 10 and 5 centipoise. Curves 1-7 and 1'-7' were constructed for the productive section of 0.5, 1, 2, 4, 6, 8 and 10 million tons/year. For example, for Q = 2 million tons/year and μ_H = 10 centipoise, on the corresponding graph of the nomogram in Figure 25 we find the intersection point of curves 3 and 3' and determined the diameter of the coalescing section D = 38 cm. The least standard size is assumed; in the given case D = 35 cm. The maximum drop size not subjected to fractionation by the turbulent oil flow and in the suspended state is 900 microns. The length of the coalescing section is defined by the formula

$$L_2 = \frac{(d^2 - d_0^2)}{0.0264KWD} \sqrt{\frac{4Q}{\pi D \nu}} + 20D. \qquad (64)$$

where d_0 and d are the initial and final sizes of the drops respectively.

The magnitude of the collision effectiveness constant K_2 was assumed equal to 0.0001 [154]. For acceleration of the calculation of the length of the coalescing section, the nomogram in Figure 34 was constructed. The required initial data were as follows: D, Q, d and ν. From the known values of d and D, a line of equal diameters and the perpendicular to the mutual intersection are drawn respectively (point I). The horizontal line to the right to intersection with the curve of given output capacity gives the point II. Dropping a perpendicular to the $L_{2\ int}$ axis, the intermediate values of the length $L_{2\ int}$ are reckoned. Then the value of the coefficient α_2 is found on the auxiliary nomogram graph by the known value of the viscosity. Then the length of the coalescing section is determined from the following expression considering the section of establishment of the flow:

$$L_2 = \alpha_2 L_{2\ int} + 20D.$$

The curves 1-5 of the nomogram in Figure 34 correspond to the output capacity of the section at 0.5, 1, 2, 5 and 10 million tons/year. Thus, for D = 30 cm, Q = 2 million tons/year, d = 370 microns, $L_{2\ int}$ = 49 meters. For ν = 20 centistokes α = 1.07; hence $L_2 = 49 \cdot 10.7 + 20 \cdot 0.3 = 56$ meters.

Determination of the Parameters of the Drop Formers in the Desalination Stage

The determination of the diameter of the section of the desalination stage is made in the same way as the coalescing section in the dehydration stage. The boundary conditions also include the possibility of the suspension of all of the drops of water in the flow for given Q, ν and other parameters. Beginning with this, the diameter of the section D is determined by the nomogram in Figure 25. The maximum drop size is found by it. The length of the line on which the given degree of encompassing of the globules of stratal water by freshwater drops is achieved with a probability of the process of 0.999 is determined using the nomogram in Figure 35 or the formula

$$L_3 = \frac{\ln\left[\left(\frac{W - W_{\text{пл0}}}{W_{\text{пл0}}^{*}}\right) \Big/ \left(\frac{W - W_{\text{пл}}^{*}}{W_{\text{пл}}^{*}}\right)\right]}{\underset{**}{\frac{K_3}{d_{\text{ср}}}} \sqrt{W\left(\frac{\pi D \nu}{4Q}\right)^{0.25}}} + 20D, \quad \begin{array}{l} \text{*stratal} \\ \text{**mean} \end{array} \qquad (65)$$

where W is the water content of the oil after introduction of fresh flushing water into it; $W_{stratal\ 0}$ is the stratal water content in the oil after the dehydration stage; $W_{stratal}$ is stratal water content in the oil after the desalination stage, having made contact with the fresh flushing water K_3 is the collision effectiveness constant; d_{mean} is the mean drop size cm; D is the diameter of the desalination section, cm; ν is the kinematic viscosity of the oil, stokes; Q is the flow rate of desalinated oil, cm^3/sec.

In order to determine the length of the desalination section using the nomogram in Figure 35, the given value of the volume of the flushing water is found on the W_{lim} axis, and on the d_{mean} axis, the mean drop size which can exist in the flow in the suspended state for the given regime of motion. From the point of intersection of the curve for the freshwater flow rate with the perpendicular dropped from d_{mean} (point I), a horizontal is drawn to the right to the intersection with the curve of the collision effectiveness constants of the drops (point II). Dropping the perpendicular from this point to the L_3 axis, $L_{3\ int}$ is reckoned. The total length of the desalination section is found considering the coefficient of the motion regimen α_3 (the auxiliary graph of the nomogram) and the section of establishment of the flow $\Delta L = 20D$:

$$L_3 = \alpha_3 L_{3\ int} + 20D.$$

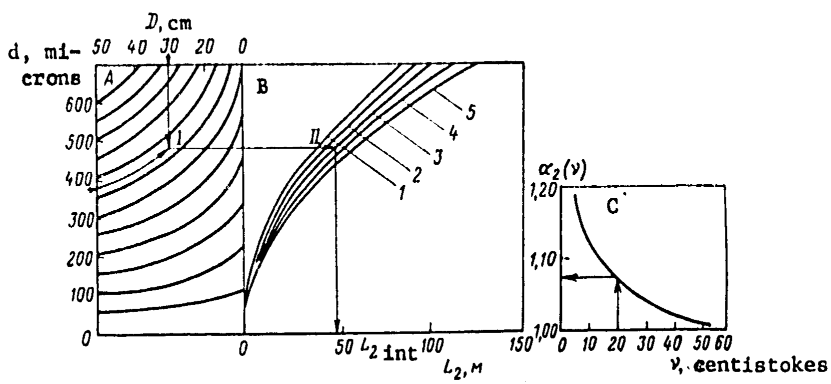


Figure 34. Nomogram for Determining the Length of the Coalescence Section of the Drop Former or the Process Line:
L--Section diameter; d_L--Drop size to which it is required to consolidate the globules; $L_{2\ int}$ is the intermediate length of the section, α_2 is the correction factor for the viscosity ν 1, 2, 3, 4,5 is the flow rate of 0.5, 1, 2, 5, 10 million tons/year.

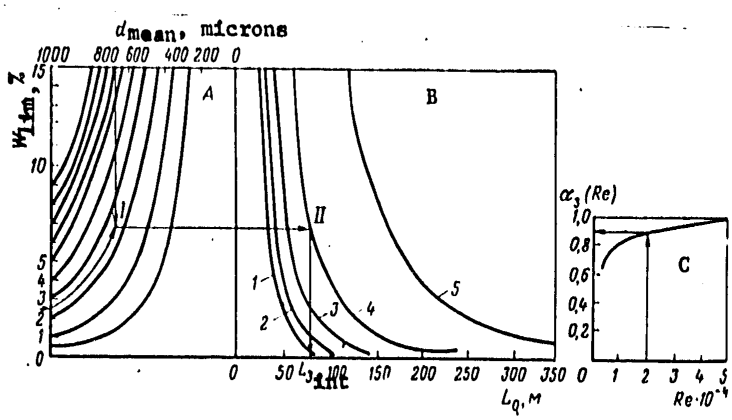


Figure 35. Nomogram for Determining the Length of the Coalescing Section of the Drop Former L_3 in the Desalinatin Stage: W_{lim} is the amount of wash water used, %; α_0 is the correction factor taking into account the motion regime; 1, 2, 3, 4, 5 are the various degrees of breakdown of the emulsion and ratio of drop sizes of the introduced flushing and stratal water.

From the nomogram it is obvious that the same degree of trapping of the drops of stratal water from the oil can be achieved for different flow rates of the fresh water. With a decrease in the freshwater flow rate, the length of the section increases. Considering the expenditures on acquiring fresh water and subsequent purification of it exceed the depreciation reckoned from the cost of the desalination section, for the calculations it is necessary to select the least acceptable level of freshwater flow rate, for example, 2-3 percent. This should correspond to the degree of dehydration of the oil in the preceding stage characterized by the residual water content in the oil of 0.1 to 0.2 percent. The section of the curve for the collision effectiveness constants depends on the method of introducing the wash water into the oil, the nature of the mixing and the ratio of the stratal and freshwater drop sizes. Depending on the existing conditions, it is recommended that the calculations be made using the following curves: 5--for an unsatisfactory dehydration process characterized by the content of a large number of globules with undisturbed shielding shells in the flow; 4--with mixing of the oil with fresh water on the mixing valves and the pressure gradients of 0.5-1.5 kg-force/cm^2; 3, 2, 1--on introduction of the previously dispersed fresh water into the flow of crude (drop size $d_{stratal} < d_{lim}$; $d_{stratal} = d_{lim}$; $d_{stratal} > d_{lim}$, respectively).

In order to obtain drops of fresh water of the required size, autonomous tubular mass exchange sections are used, the parameters of which are selected with the help of the nomograms in Figures 32-33 or forcing with the calculated nozzle parameters.

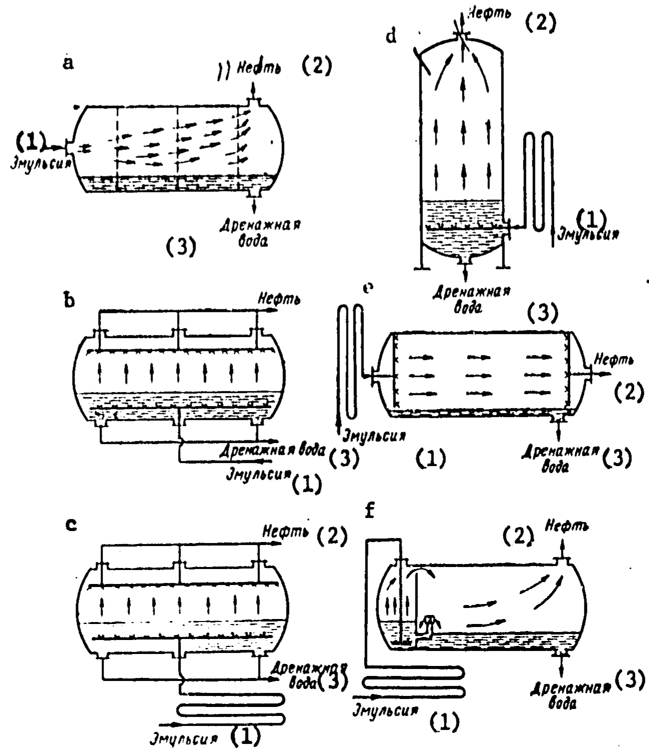


Figure 36. Schematic Diagrams of the Settling Tank Installations of Various Types:
a--With perforated grating; b--With lower distribution input of the emulsion under the drainage water level and upper distributed removal of the oil; c--With sectional drop former, low distributed input of the emulsion and upper distributed removal of the oil; d--Vertical with sectional drop former and low distributed input of the emulsion under the layer of drainage water; e--With end distribution units for introducing the emulsion and removing the oil; f--With overflow baffle and flushing of the oil in the drainage water layer.

Key: (1) Emulsion
(2) Oil
(3) Drainage water

Settling Equipment

Volumetric Units

The problem of creating highly efficient settling equipment has in recent years become one of the most urgent problems. The high rates of increase in the volumes of oil extraction and preparation, its concentration in enormous amounts at the central collection points have required the creation of high-output settling equipment. The application of the settling equipment with previous technological process characteristics unavoidably leads to the creation of expensive and metal-consuming industrial complexes, the involvement of large plots of ground in the process sites, the use of a significant amount of control and regulating equipment and fittings, complication of servicing, and so on.

Until recently the improvement of the structural design of the settling installations has developed along two basic lines:

Improvement of the hydrodynamics inside the units for more complete utilization of their useful volume (distribution units, baffles, and so on) (see Figure 36);

Intensification of the process of coalescence of the globules of stratal water and separation of it from the oil (baffles which change the direction of flow, the introduction of emulsion under a layer of water, the application of an electric field, the application of vibrations to the boundary layer, and so on) (see Figure 36). However, here the achieved level of output capacity turned out to be low, and the problem remained as before in practice unresolved. Thus, the loading of the best settling installations with respect to fluid to a volume of 200 m^3 amounts to 1.2-1.3 million tons/tons/year. The problem consists in creating equipment with an output capacity exceeding this level by several times. The theoretical prerequisites explaining the possibility of achieving this level reduced to the following [130].

The output capacity of the horizontal units of cylindrical shape can be calculated by the formula suitable for drops less than 0.1 mm in size (the sedimentation regime in laminar):

$$Q_л = \frac{gd^2 \Delta\rho L \{\pi R^2 + 2 [R + \sqrt{h(2R-h)}] (R-h)\}}{36 R \nu \rho_н}, \qquad (66)$$

where Q_ℓ is the output capacity; g is the gravitational acceleration; d is the diameter of the stratal water globules; $\Delta\rho$ is the difference in water and oil densities; L is the length of the unit; R is the radius of the unit; h is the height of the water cushion; ν is the kinematic viscosity of the oil; ρ_H is the density of the oil.

For h = 0 the formula assumes the form:

$$Q_{л}^{!} = \frac{0.143 R g d^2 \Delta\rho L}{\nu\rho_{н}}. \tag{67}$$

From formula (67) it is obvious that the output capacity of the settling tank depends on the dimensions of the stratal water globules to the second power. Thus, the increase in drop size by only 3.3 times leads to an increase in output capacity of the settling tanks by 10 times. The other parameters influence the output capacity of the settling tanks linearly. Hence it follows that in order to increase the output capacity of the settling tank unit the latter must be equipped with devices capable of consolidating the drops before the emulsion enters the stagnation zone. This must be preceded by completion of the mass exchange processes with respect to bringing the reagent to each globule of stratal water and destruction of the protective shells in them. With an increase in the drop size to 0.1 mm or more the sedimentation rate increases, the sedimentation regime becomes turbulent and the output capacity of the settling tank is determined by the formula

$$Q_{т} = \frac{2.75 L R \sqrt{g d \Delta\rho}}{\sqrt{\rho_{н}}}. \tag{68}$$

The analysis of formulas (67) and (68) and also their comparison indicates that Q_T is two orders more than Q_{ℓ}. Consequently, theoretically the output capacity of the settling tanks can be increased by 100 times under the condition of preliminary consolidation of the drops. If we consider a number of factors limiting the possibility of increasing the output capacity of the settling tanks to this level under practical conditions, the possible loading of the units turns out to be 10 times higher than that achieved on the average with respect to the branch.

Therefore it is necessary:

To realize preliminary consolidation of the emulsion drops before their introduction into the stagnation zone or stratification of the emulsion;

Ensure the end uniform input of the liquid with respect to the cross-section of the unit and also the uniform sampling of the liquid;

Maintenance of a low level of the water cushion or in practice exclusion of it;

Exclusion of the operation of "flushing" the emulsion through the drainage water layer from the settling zone.

The devices which permit the drop size to be increased before the emulsion reaches the settling zone can be the hydrodynamic type tubular and volumetric drop formers. The tubular drop formers have already become widespread in the deposits; the volumetric ones are in the development stage. Their application has in individual cases made it possible to increase the output capacity of the settling tank unit with a volume of 200 m^3 to 4.05 million tons/year (the Biryuchevskaya Thermochemical Units of the Tatneft' Association).

While keeping the output capacity invariant, the use of the drop formers permits improvement of the quality of the oil by 5 to 10 times. The flushing of the emulsion through the water layer during processing of the undisturbed emulsion unconditionally has played a positive role, for it has promoted a reduction in strength of the protective shells on the drops of stratal water and transition of a significant number of them to the drainage water tank. During the processes of breaking down the emulsion and coalescence of the drops in the drop formers the necessity for flushing is removed, and its exlusion permits the output capacity of the settling tanks to be increased, for in this it becomes possible to remove part of the drops by the ascending oil flow.

The output capacity of the settling tanks with rectangular cross-section under the condition of motion of the liquid perpendicular to the direction of the gravitational force (the terminal input) is determined by the equality:

$$Q' = F\omega'_{oc},$$

where ω'_{sed} is the sedimentation rate.

The maximum output capacity of the settling tank with the tap at the top is determined by the equality of the velocities of the ascending flow and the settling of the drops in the vicinity of the oil-water phase interface, the size of which is taken into account when calculating

$$Q'' = F\omega''_{oc},$$

where $\omega''_{sed} = \omega'_{sed} - \omega_{liquid}$ is the resultant sedimentation rate; ω_{liquid} is the speed of the ascending flow of liquid.

However,

$$\omega_{liquid} = \frac{Q''}{F};$$

from which

$$\omega''_{sed} = \omega'_{sed} - \frac{Q}{F};$$

consequently:

$$Q'' = F\left(\omega'_{oc} - \frac{Q''}{F}\right) = F\omega'_{oc} - Q'';$$

or

$$Q'' = \frac{F\omega'_{oc}}{2}.$$

The ratio Q'/Q'' gives the expression

$$\frac{F\omega'_{oc}}{\frac{F\omega'_{oc}}{2}} = 2,$$

from which it follows that the output capacity of the settling tanks with end distributed input under actual conditions can be twice the output capacity of the settling tank with low input distribution operating with a water cushion inasmuch as $\omega'_{sed} > \omega''_{sed}$. The semi-industrial tests demonstrated that the output capacity of the settling unit with a drop former and terminal input can be brought to 9 million m^3/year (see Figure 37).

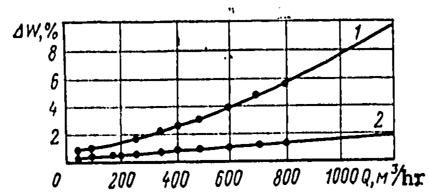


Figure 37. Oil Quality as a Function of the Output Capacity of the Settling Tank Installations:
1--Settling tank with low distributed input and flushing of the emulsion in a layer of water; 2--Settling tank with sectional drop former and end distributed input; ΔW--residual water content in the oil

The maximum output capacity of the settling tank achieved under practical conditions in the dehydration stage is 4 million tons/hour. In the desalination stage for Devonian oil (Romashka) settling tanks have been tested with an output capacity of 2.1 to 3.6 million tons/year. If we consider that the average load of the settling tank installations on such units as the Karabashkaya UKPN Refinery is 0.167 million tons/year then it becomes important how many reserves industry has its disposal. For oil with increased viscosity, a somewhat different picture has been put together (the Bondyuzhskaya oil). Here the maximum output capacity was 2.7 million tons/year, which, however, is not the limit.

Selection of the Volumetric Settling Tank Installations

The output capacity of the settling tank installation of field and plant units for treating oil is determined by the degree of disperseness of the drops of water, the viscosity of the oil and other parameters influencing the stratification rate of the oil and water emulsions. The technological procedures directed at the degree of consolidation of the stratal water drops before the emulsion stands have a decisive effect on the increase in output capacity of the settling tank installations under equal conditions. When a large number of drops settle, the rate of constricted fall ω is determined not only by the parameters entering into the expression for the Stokes Law, but also the ratio of the emulsion phase volumes. In reference [25], on the basis of the experimental studies of the constricted sedimentation, an empirical relation is presented which takes this factor into account and which, after some transformations, can be represented as follows:

$$\omega = \frac{\Delta\rho g d^2}{18\mu_H} \frac{(1-W)^{4,75}}{\left[1 + \frac{1}{30}\sqrt{\frac{gd^3}{\nu_H^2}\frac{\Delta\rho}{\rho_H}(1-W)^{4,75}}\right]}, \qquad (69)$$

where μ_H is the actual viscosity of the oil, poise; $\Delta\rho$ is the difference in density of the water and oil, g/cm^3; g is the gravitational acceleration; d is the drop diameter, cm; W is the relative water content of the oil; ν_H is the kinematic viscosity of the oil, stokes; ρ_H is the oil density, g/cm^3.

The first cofactor in formula (69) is the sedimentation rate of a single particle in accordance with Stokes Law, and the second cofactor is a correction for the conditions of constricted sedimentation. It has been established that for calculating the stratification in the settling tank unit of water and oil emulsions, expression (69) can be simplified.

The following values are presented in Table 2

$$\beta = 1\Big/\left[1 + \frac{1}{30}\sqrt{\frac{gd^3}{\nu_H^2}\frac{\Delta\rho}{\rho_H}(1-W)^{4,75}}\right],$$

calculated for the characteristic conditions: ρ_H = 0.8 g/cm^3; ρ_B = 1.1 g/cm^3; ν_H = 0.1 stokes.

The data obtained make it possible to arrive at the conclusion that for water and oil emulsions it is possible to neglect the value of β, and during the sedimentation calculations, to use the formula

$$\omega = \frac{\Delta\rho g d^2}{18\mu_H}(1-W)^{4,75}. \qquad (70)$$

Table 2

W	Value of β for water drops size, microns				
	50	100	200	400	500
0,05	0,998	0,995	0,986	0,963	0,948
0,1	0,999	0,996	0,988	0,967	0,955
0,2	1,000	0,997	0,991	0,975	0,965
0,3	1,000	0,998	0,993	0,981	0,975
0,4	1,000	0,999	0,996	0,987	0,982
0,5	1,000	1,000	0,998	0,992	0,988
0,6	1,000	1,000	1,000	0,996	0,993

The error for the range of variation of the water drop size from 50 to 500 microns does not exceed 4-5 percent. The nomogram constructed considering the above-investigated factors will permit rapid determination of the type and required number of settling tanks. In this case the calculation of the settling tank units reduces to determination of the number and type of settling tanks required for dehydration and desalination of the oil for the given technological process parameters and the selected sections of the drop formers. The required initial data are as follows: d, μ_H (or T, °C), V--volume of the settling tank installation, m^3, and W--relative volumetric content of water in the oil.

The procedure for calculating the number of units for a degree of dehydration is as follows: being given the drop size at the output from the drop former and the viscosity of the oil, the nomogram in Figure 38 was used to determine the intersection point of the perpendicular reproduced from the value of μ_H with the curve for the given drop diameter (point I). Drawing a horizontal line to the right from the point obtained to the curve corresponding to the selected volume of the settling tank installation, we obtain the point II. The perpendicular from this point to the Q axis gives an output capacity of the settling tank of the selected volume Q_{lim}. The correction for the restricted conditions of sedimentation K_{res} taking into account the water content of the crude oil going into the settling tanks is selected on the auxiliary graph D of the nomogram in Figure 38. Finally, the output capacity is defined as

$$Q = Q_{lim}/K_{st}.$$

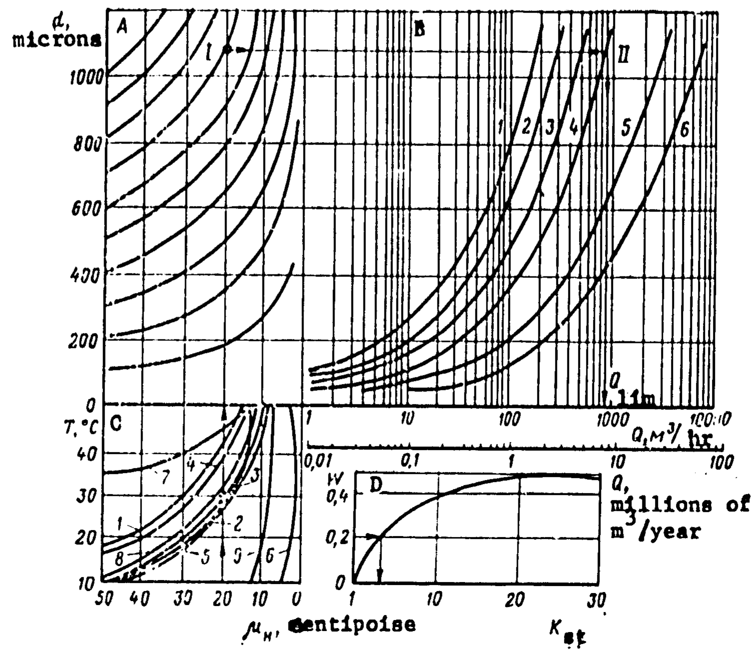


Figure 38. Nomogram for Calculating the Output Capacity of the Settling Tank Installations:
Quadrant A: drop size curves; Quadrant B: 1-6--Settling tanks with a volume of 28, 50, 100 and 200 m^3 and tanks with a volume of 2,000 and 5,000 m^3; Quadrant C: 1-9--Viscosity as a function of the temperature respectively for the oil of the Romashka coal bearing, Bavlinskaya coal bearing, Romashka Devonian, Zapadnosurgutskaya, Ust'-Balykskaya; Samotlorskaya; Mangyshlak; Arlanskaya; the red Yar deposits.

The required type of settling tank installation is selected beginning with the output capacity of the unit, the sizes of the area for installation of them and other factors. The number of settling tanks is determined by the formula

$$n = Q/V.$$

Curves 1-6 of the nomogram in Figure 38 correspond to the volume of the settling tanks of 28, 50, 100, 200 m^3 and the tanks 2,000 and 5,000 m^3. Curves 1-9, which are the oil viscosity of different oil extracting regions as a function of temperature, are analogous to the curves on the nomogram in Figure 32. For example, on consolidation of the drops in the coalescing section to a value of d = 700 microns, the viscosity of the oil μ_H = 20 centipoise and the water content W = 20 percent, the settling tank with a volume of 200 m^3 has the output capacity (m^3/hr):

$$Q = \frac{900}{3} = 300.$$

With an output capacity of the dehydration unit of 2 million tons/year it is necessary to use one settling tank with a volume of 200 m^3. The procedure for calculating the settling tank installations for the desal' ation stage is the same as for the dehydration stage. Here the drop sizes can be taken into account which can exist in the flow at the exit from the section of the desalination stage. For both stages it is proposed that we use a reserve settling tank, the fittings for which make it possible to connect it when necessary both to the dehydration stage and to the desalination stage.

The Operation of the Settling Tanks in the Optimal Monitoring Mode

One of the conditions ensuring operating reliability of the process equipment and stability of the regimen parameters of the devices for field treatment of the oil is precise regulation of the oil-phase water interface in the settling tank installations. This to a great extent determines the quality of the oil treated on the unit and the discharged waste water. Therefore each settling tank installation or electrodehydrator is equipped with level regulators. Since on the standard oil treatment units up to 30 settling tank installations are used (the Karabashskaya UKPN with a capacity of 6 million tons/year), the servicing, preventive maintenance, repair and level regulation are greatly complicated. Accordingly, the flow charts for hooking up the settling tank units permitting a significant decrease in the requirement for level regulators and a reduction in the degree of their influence on the operation of the units and quality of the oil prepared in them are of significant interest. With a decrease in the number of level regulators in the settling tank unit, not only does the number of service points diminish, but better quality preventive maintenance and reliable monitoring of the operation of the latter become possible. With respect to the optimal monitoring scheme the following are provided for:

The installation of a level regulator in one or two units with realization of hydrodynamic connection between these operating settling tanks;

Return of all of the drainage water to the process cycle for preparation of the oil.

With respect to the flow chart for the dehydrating unit operating in the optimal monitoring mode, the quality control is realized on the stratal water in the stage of preliminary discharge along with control of the quality of the oil at the exit from the settling tank 10 operating in the flow stratifier mode (see Figure 39). In accordance with this scheme, the well production treated with reagent in the field lines reaches the separator 3. The emulsion which has been degased and broken down in advance is sent through a hydrodynamic drop former 4 into the preliminary water discharge settling tank. The introduction of hot drainage water into the emulsion flow ahead of the separator 3 or the drop former 4 ensures purification of it to the degree permitting it to be pumped into the bed, it promotes consolidation of the globules of stratal water and fast separation of the phases in the settling tank 5. At the exit from the latter, the quality of the discharge drainage water is monitored by using the analyzer 19.

With a content of pollutants in the water above the admissible norms, it is purified in the settling tank 16 using the liquid hydrophobic filters. The oil leaving it with a water content of 5 to 7 percent is heated in the heat exchanger 7 to a temperature of 40° C and is fed by the pump 6 through the drop former 8 to three out of four of the available settling tanks 9 and then to the water separator settling tank10, the fittings of which permit inclusion of it in series and in parallel with the settling tanks 9. The setting tank 10 is hydrodynamically connected with the settling tanks 9. It can be in the same unit with it, and it is regulated by the quality of the oil coming out of it. The regulator of the interface level is installed in this settling tank or in another one of them. The active drainage water is fed to the intake of the separator 3 after the units 9-10.

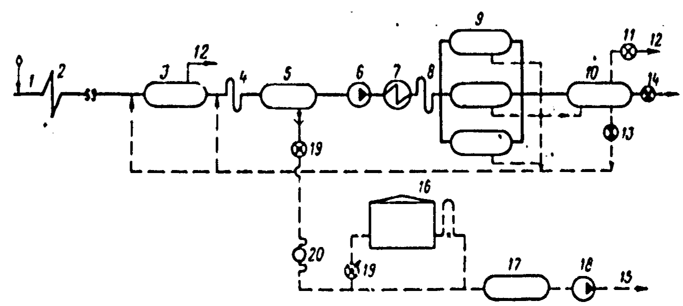


Figure 39. Flow Chart of the Fittings of Settling Tanks for the Oil Treatment Unit Operating in the Optimal Monitoring Mode:
1--Demulsifier batcher; 2--Line used for breaking down the emulsion; 3--Separator; 4--Cold stage drop former; 5--Preliminary water discharge tank; 6--Pump; 7--Heater; 8--Hot stage drop former; 9--Settling tank; 10--Tank for water discharge; 11--Gas drier; 12--Gas line; 13--Drainage water meter; 14--Meter and quality analyzer of the prepared oil; 15--Purified water line to the pump; 16--Settling tank with hydrophobic liquid filter; 17--Buffer tank; 18--Pump; 19--Meter and quality analyzer for the drainage water; 20--Hydrodynamic tubular coalescer.

The layout by this flow chart excludes the necessity for quality control of the drainage water discharged from the settling tank, for the latter is purified in the oil preparation process cycle where the drops of oil removed with the water are returned to the common flow of incoming production of the wells. The investigated process permits significant improvement of the system, monitoring of the quality of the water and oil and a simultaneous decrease in the total number of required level regulators.

Tubular Settling Tanks

From the above investigated materials it follows that in many cases the volumetric settling tanks can be replaced by tubular ones. It is easy to demonstrate that the output capacity of the settling tank with radius R is equal to the sum of the output capacities of the group of settling tanks with radii $r_1, r_2, \ldots, r_n$ under the condition that

$$R = \sum_{i=1}^{i=n} r_n \quad \text{and} \quad L_R = L(r_1, r_2, \ldots, r_n).$$

Indeed, if we set:

$$Q = AR; \quad Q_1 = Ar_1;$$
$$Q_2 = Ar_2; \quad Q_n = Ar_n,$$

where A is the coefficient equal to the numerical value of the remaining parameters in the formula for the output capacity of the settling tank and we take the sum from Q_1 to Q_n, we obtain

$$\sum_{i=1}^{n} Q_i = A(r_1 + r_2 + r_3 + \ldots + r_n).$$

For $R = r_1 + r_2 + r_3 + \ldots + r_n$, we obtain

$$\sum_{i=1}^{n} Q_1 = AR;$$

hence, it follows that

$$Q = \sum_{i=1}^{n} Q_1.$$

In other words, one unit of radius R can be replaced by banks of tubes with small diameter of the same length under the condition that the sum of the radii of these tubes will be equal to the radius of the large settling tank. This opens up the way to the creation, for example, of small, portable and nonmetal consuming settling tank installations. It is natural that the increase in output capacity of the settling tank installations is connected with the necessity for varying the hydrodynamic flow regime and increasing the speed of the liquid in them to values characterizing the turbulent flow. The factor limiting the output capacity of the settling tank units with properly selected hydrodynamic characteristics is the transverse pulsation components of the velocity operating against the gravitational forces.

In Figure 27 (curves 1-4) a graph is presented for the turbulent flow pulsations as a function of the diameter of the unit with a Reynolds number of 10,000 from which it follows that the diameter of the settling tank under other equal conditions, for example, average flow velocity, is one of the defining parameters influencing the possibility of stratification of the emulsion with moderate turbulent regime characterized by the Reynolds numbers of order 5,000 to 20,000.

In accordance with [211], the length of the settling tank unit on which the process of stratification of the emulsion can be completed in the laminar regime of motion, is defined by the following expression:

$$L_{л} = \frac{4}{3}\frac{u_{max}}{u_{ст}} D, \qquad (71)$$

where u_{max} is the speed of the laminar flow along the axis of the settling tank; u_{CT} is the gravitational sedimentation rate of the drops; D is the diameter of the unit.

For settling of the drops on the bottom of the tubular settling tank from a flow moving in the turbulent regime, the required length of the unit is determined by the expression:

$$L_{т} = \frac{v_{max} - \frac{1}{\varkappa} v^{*}}{u_{д}} D, \qquad (72)$$

where v_{max} is the maximum flow velocity; $\varkappa$ is the turbulence constant; u_D is the dynamic settling rate.

Figure 28 shows the length of the units of different diameter as a function of the water drop size required for stratification of the turbulent flow of the emulsion characterized by the Reynolds number of 10,000 for an oil viscosity of 0.044 poise.

As was pointed out earlier, there is a limiting size of the drops which can settle in a unit of given diameter. This fact is reflected on the curves by a sharp increase in length of the unit when the drop diameter approaches the maximum. With an increase in drop diameter, the length of the settling tank required for stratification of the flow is significantly reduced. The analysis of the curves in Figure 28 makes it possible to draw the conclusion of the possibility of rapid stratification of the emulsion in the horizontal tubular units, the diameter of which is appreciably less than 3 meters. The preliminary consolidation of the finely dispersed part of the emulsion will permit realization of this process during its movement in the turbulent regime with high output capacity. Thus, for example, the stratification of the emulsion with drop sizes of 600 microns turns out to be identically attainable both in the settling tank with a diameter of 50 cm, the length of which is small--near 3 meters--and in the standard settling tank with a diameter of more than 3 meters. In the latter case the required length of the settling tank is 2 meters. On consolidation of the drops to 8 microns the settling of the water from the oil becomes possible in the settling tanks with a diameter of 20 and 10 cm respectively. Hence, it follows that the realization of the principle of preliminary consolidation of the drops before sending the emulsion to the settling tank opens up the possibilities for the creation and use of small high output water separating equipment made of tubes.

The theoretical possibility of stratification into oil and water of the emulsion with drops consolidated in advance in the tubular elements under turbulent conditions was checked out under industrial conditions at the ELOU-1 NGDU [Oil and Gas Extraction Administration] Bavlyneft' (Tatneft' Association) which processes oil from the coal-bearing horizons.

The breakdown of the emulsion and the hydrodynamic consolidation of the drops before the water settles out of the oil were realized using the sectional drop former, and the stratification of the flow into oil and water, in the experimental tubular settling tank. The sectional drop former consisted of the series connected heat insulated tubular elements 150 and 250 mm in diameter laid on a foundation. The heat insulated tubular settling tank was made of tubes 350 mm in diameter. At the end of the settling tank there were two taps for discharge of the separated water and tapping the desalinated oil. The unseparated mixture of water and oil from the intermediate turbulence zone was removed through the central tube 150 mm in diameter. It usually quickly stratifies with subsequent finish of the settling. The flow rate of the prepared oil and drainage water tapped off was controlled by the Voltman meters. The time for movement of the oil through the first section of the drop former was 5 minutes (with Re = 21,000); in the second section, 12 minutes (with Re = 14,000) and in the turbulent settling tank, 12 minutes (with Re = 8,000).

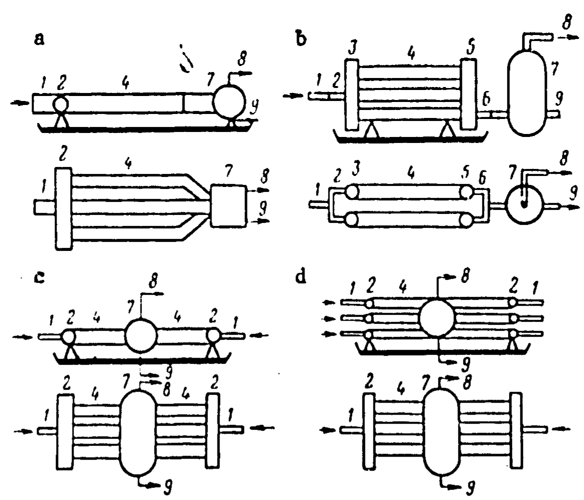


Figure 40. Tubular and Combined Settling Tanks:
a--Horizontal, single row; b--Vertical, multirow; c--Horizontal two-way, multirow; d--Multilayer, horizontal, two-way, multirow; 1--Output emulsion; 2--Horizontal distributor; 3--Vertical distributor; 4--Tubular settling elements; 5--Vertical collector; 6--Horizontal collector; 7--Tank; 8--Oil output; 9--Water discharge.

The oil was treated by the following flow chart. The oil from the coal bearing horizon (3,500-4,000 tons/day) with a water content of 30 to 40 percent reached the tank for preliminary discharge of the water and hence, with a residual water content to 12 percent and the reagent introduced into it (from calculations of 50 g/ton) it went to the heat exchangers where it was heated to 60° C and then, passing through the sections of the drop former, it went to the tubular settling tank.

Observations have demonstrated that for deep destruction of the protective shells and preliminary enlargement of the globules of the emulsion in the drop former sections, the stratification of the flow into oil and water in the settling tank 35 cm in diameter is realized for values of the Reynolds numbers on the order of 8,000. Hence it follows that up to these values of the parameter Re the output capacity can also be increased for the standard settling tank installation. It was noted that a layer of pure drainage water moved in the lower part of the tubular settling tank. Its central section, including the contact zone with the water was represented by oil dehydrated to 1.6-2 percent, and the upper section, dehydrated oil. The intermediate zone itself contained no more than 2-4 percent water. Here it turned out that the stratification of the mixture of water and oil picked up from this zone takes place in 15 minutes with a temperature of 45° C.

Analogous results were achieved when using a tubular complex also in the desalination stage. In this case the fresh water, calculating 8 percent of the treated oil, was supplied at the beginning of the drop former section 150 mm in diameter.

It was established that during the process of the joint movement of the coal-bearing oil and fresh water through the sectional drop former, effective desalination of the oil takes place and, on reduction of the turbulence level to a value of Re = 14,000 (at the end of the section of the drop former 250 mm in diameter), the basic amount of wash water is isolated in the lower part of the drop former. The process of stratification of the emulsion with Re = 8,000 is completed in the tubular settling tank in the section 10 meters long. The total amount of desalinated oil to 50-120 mg/liter picked up directly from the tubular settling tank reached 25 percent of the output capacity of the unit. Simultaneously, 85 to 90 percent of the drainage water was discharged out of its total content in the oil [78, 179, 191].

The unstable mixture of water and oil from the intermediate zone, for the stratification of which no more than 15 minutes are needed, was picked up through a separate line.

The calculations demonstrated that the modular tubular complex including the two-section drop former and the settling tank with an expanded with an output capacity 1 million tons/year weighs 25 tons. The series settling tank units operating under analogous conditions with the same total output capacity weight 144 tons, that is, 5 times more. The savings from introducing one tubular settling tank with a drop former (with an output capacity of 1 million tons/year) amount to 53,000 rubles/year.

The increase in output capacity of the existing settling tank equipment can be achieved also by using the advantages characteristic of both the volumetric and tubular settling tanks (see Figure 40). It is necessary to consider the possibility of using the volumetric units simultaneously as a distributing device and a drop former and also a stratifying tank suitable for picking up oil and water in large amounts among their advantages. The quality of the water in this case is such that it can often be pumped into the bed without additional purification. The advantages of the tubular units come from their low metal consumption, simple installation and convenience. The creation of the combined units provides for combined installation of the tubular and volumetric elements in a combination which corresponds to the stated process goals. For example, several tubular settling tanks with drop formers can be blocked with one large volume settling tank, and included in it as in a separating tank.

The use of the above investigated principles and the creation of the highly productive settling equipment on the basis of it equipped with tubular drop formers has made it possible to bring the problem of the complete seal of the collection and transportation of the well production in the "well-oil treatment complex" interval to a practical level. For the solution of the problem [91] it was proposed that part or all of the settling tank equipment in the first stage of the desalinating units equipped with drop formers be used as the preliminary water discharge units. In the latter case, quite deep dehydration of the oil must be achieved permitting desalination of it in the subsequent stages. Here the transportation of the emulsion from the field is realized by the scheme providing for pumping of it directly into the unit, bypassing the preliminary discharge tanks. The existing settling tank equipment and drainage system for the units in this case must be suitable for discharge of the entire volume of water reaching the complex with the oil. The preliminary water discharge unit in this case is excluded from the set of field equipment.

On the whole, the prospects for increasing the output capacity of the settling tank installations, the creation of modular small-sized equipment on the basis of this for treating oil and water with high output capacity and low metal consumption and also obtaining pure drainage water directly from the process units for treating the oil are connected with the observation of the following process principles:

Consolidation of the drops of stratal water to desalination of the flow into oil and water in the process of movement of the emulsion from the wells to the settling tank installation and the use of the field collection systems and built-in drop formers for these purposes;

A reduction in the flow turbulence with respect to direction of motion of the emulsion toward the settling tank units;

Realization of terminal distributed input and pickup of the oil in the settling tank units;

The hook up of the settling tank installation so that the drainage water is returned to the head of the process for primary purification and demulsification of the oil and its operation in the optimal monitoring regime.

Modular Demulsifiers

The industrialization of the structures for field treatment of oil by using factory-built modular automated equipment will theoretically make it possible to find efficient solutions to many of the problems connected with field equipment, in particular, a reduction in capital investments, metal consumption, a reduction in construction time, decrease in size of the process sites, and so on [64]. However, these problems can be solved only if the output units have high capacity and ensure that high quality oil is obtained. Industry has built a large number of demulsifiers in different versions, many of which have operated for a long time. Depending on the methods used to break down the emulsion, the demulsifiers can be classified in two groups, corresponding to the second and third levels of treating the oil. As has already been noted, the second level corresponds to the process and the equipment (in addition to the settling operation) providing for the application of some means of intensifying the breakdown of the protective shells on the globules of stratal water (heating, treatment with demulsifier, use of drainage water). The third level corresponds to the units and the process in which, along with the noted ones, various methods of coalescence of the drops are used (the coalescing filters, electric field, hydrodynamic coalescers and drop formers).

Considering that the modern process of preparing the oil is reckoned at six levels, it is easy to see that the demulsifiers produced by the industry of different countries have become obsolete and are in need of modernization. The characteristics of certain types of demulsifiers developed by the American BSB Company are presented in Table 3. From the data in the table it is obvious that the output capacity of the units permits their use in small formations, but in medium and large ones, too large a number of them would be required to dehydrate the oil. In addition, the units are designed for obtaining oil with a residual water content of about 2 percent, which at the present time cannot be considered satisfactory.

Analogous equipment used in the Soviet fields also fails to provide high output capacity with high quality of the treated oil.

The analysis of the flow charts for the oil treatment units[1] which include the type SP units, has demonstrated that out of 97 SP-1000 (SP-2000) demulsifiers, less than 25 percent have operated in the mode of dehydration of the oil with a degree of treatment noted at the output from the unit to 1-2 percent. The remaining SP-1000 (SP-2000) emulsifiers in the oil treatment units were used as heaters before the preliminary water discharge tanks (NGDU Shaimneft', Nizhnevartovskneft') or ahead of the settling tanks and the tanks for preliminary discharge of the water.

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1. Performed at the VNIISPTneft' Institute.

Table 3

	(1) Эмульсия	(2) Деэмульсатор	(3) Размеры, м	(4) Давление, кгс/см²	(5) Производительность (6) по жидкости, м³/сут	(7) по нефти, м³/сут	(8) по газу, тыс. м³/сут
(9)	Нормальная	(10) Вертикальный тип S	1,20 × 6,0	1,5—3	50—2170	15,5—600	30—360
(11)	Стойкая	(12) Термохимический тип N	1,2 × 8,2	1,5—3	67—2170	15,5—600	60—360
	»	(13) Горизонтальный, термохимический		2—4	370—3000	102—1620	20—200

Key:
(1) Emulsion
(2) Demulsifier
(3) Dimensions, meters
(4) Pressure, kg-force/cm^2
(5) Output capacity
(6) With respect to the liquid, m^3/day
(7) With respect to oil, m^3/day
(8) With respect to gas, thousands of m^3/day
(9) Normal
(10) Vertical type S
(11) Stable
(12) Thermochemical type N
(13) Horizontal, thermochemical

With the exception of the oil preparation units of Glavtyumenneftegaz and NGDU Tadzhikneft' Administration in which the output capacity of the units reached 1,300 to 2,000 m^3/day, the actual load of the unit turned out to be 2 to 3 times less than the projected load. However, even under such conditions the SP-1000 (SP-2000) separators turned out to be ineffective both as demulsifiers and as heaters (Table 4).

In contrast to the type SP units, the UDO type demulsifiers were designed for a large output capacity (to 3000 m^3/day). Some of the results of their operation are presented in Table 5.

It is inexpedient to use the UDO-2M and UDO-3 units in the heater mode, for the thermal efficiency of these units and their other technical-economic characteristics are much lower than for the NN-2,5 and NN-6,3 modular heaters (see Table 6). The thermochemical demulsifiers which do not have effective coalescing devices and both in the Soviet oil refineries and abroad are being forced out by the improved electrical dehydrators of various types (horizontal, vertical, ball) quite completely investigated in references [8, 198, 64].

Table 4

(1) Объединение, НГДУ	(2) Производительность, м³/сут	(3) Деэмульсатор (4) содержание воды в нефти, %		(5) Подогреватель (6) температура, °С	
		(7) на входе	(8) на выходе	(7) на входе	(8) на выходе
(9) НГДУ Удмуртнефть	750	17,8	До 2	5—14	30
(10) Объединение Сахалиннефть					
(11) НГДУ Востокнефть	700	20	До 2	4—10	30
(12) НГДУ Эхабанефть	230	10	До 3	12	30
(13) Объединение Белоруснефть, НГДУ Речицанефть	800	5—20	До 3	17	32
(14) Объединение Узбекнефть, НГДУ Андижаннефть	450	12—50	2—8	23	40—45
(15) Объединение Татнефть, НГДУ Сулеевнефть	270	—	—	8	25
(16) Объединение Пермнефть					
(17) НГДУ Осинскнефть	680	—	—	18	30
(18) НГДУ Кунгурнефть	900	—	—	18	35
(19) НГДУ Таджикнефть	350	—	—	22	48

Key:
(1) NGDU Association
(2) Output capacity, m^3/day
(3) Demulsifier
(4) Water content in the oil, %
(5) Heater
(6) Temperature, °C
(7) At the input
(8) At the output
(9) NGDU Udmurtneft'
(10) Sakhalinneft' Association
(11) NGDU Vostokneft'
(12) NGDU Ekhabaneft'
(13) Belarusneft' Association, NGDU Rechitsaneft'
(14) Uzbekneft' Association, NGDU Andizhanneft'
(15) Tatneft' Association, NGDU Suleyevneft'
(16) Permneft' Association
(17) NGDU Osinskneft'
(18) NGDU Kungurneft'
(19) NGDU Tadzhikneft'

Table 5

(1) Объединение, НГДУ	(2) Тип	(3) Число	(4) Производительность, м³/сут	(5) Содержание воды в нефти, % (6) на входе	(7) на выходе	(8) Температура, °С (6) на входе	(7) на выходе	(9) Режим работы аппарата по схеме
(10) Объединение Татнефть, НГДУ Джалильнефть	(19) УДО-3	2	3000—4500	—	—	5	30	Подогреватель (20)
(11) Объединение Башнефть, НГДУ Чекмагушнефть	(22) УДО-2М	1	4000	—	—	20	30	»
(12) Объединение Пермнефть, НГДУ Чернушканефть	(19) УДО-3	2	1600—3000	7—8	0,9	-25	30	Деэмульсатор (21)
(13) Объединение Саратовнефть								
(14) НГДУ Правобережное	(22) УДО-2М	1	1600—3000	—	—	10—15	35	Подогреватель (20)
(15) НГДУ Заволжское	УДО-2М	3	1300	8,0	0,8	25	70	Деэмульсатор (21)
(16) Объединение Нижневолжскнефть, НГДУ Арчединское	(23) УДО-2Н	2	550—600	38,0	0,5	18—20	60	»
(17) Объединение Сахалиннефть, НГДУ Востокнефть	(22) УДО-2М	1	500—800	19,0	0,5	4—10	30—40	»
(18) Объединение Мангышлакнефть	УДО-2М	11	1300	16,0	0,8—5,0	30	65	»

Key:
(1) Association, NGDU
(2) Type
(3) Number
(4) Output capacity, m^3/day
(5) Water content in the oil, %
(6) At the input
(7) At the output
(8) Temperature, °C
(9) Operating conditions of the equipment according to the following scheme
(10) Tatneft' Association, NGDU Dzalil'neft'
(11) Bashneft' Association', NGDU Chekmagushneft'
(12) Permneft' Association, Chernushkaneft' NGDU
(13) Saratovneft' Association
(14) NGDU Pravoberezhnoye
(15) NGDU Zavolzhskoye
(16) Nizhnevolzhskneft' Association, NGDU Archedinskoye
(17) Sakhalinneft' Association, NGDU Vostokneft'
(18) Mangyshlakneft' Association
(19) UDO-3
(20) Heater
(21) Demulsifier
(22) UDO-2M
(23) UDO-2N

In the socialist republic of Romania, the electrodehydrator of the system developed by Engineer Nikodimesku is used which is constructed on the basis of a tank operating on industrial frequency currents (Figure 41) at atmospheric pressure. The electrodehydrator has four horizontal electrodes forming three electric field zones [48]. The diameter of the electrodehydrator is 12 meters, the height is 7,84 meters, and the volume is 855 m^3. The reticular electrodes 7 are connected to the feed sources, and the electrodes 6 are grounded. The voltage between the electrodes 7 reaches 35 kilovolts, and between the electrodes 6-7, about 17.5 kilovolts.

The oil is heated using coils through which steam is feed. The electrode 6 is made up of a solid sheet of steel, and, in addition to the primary role, it also plays the auxiliary role of a shield which changes the direction of the flow along the electrodes. This has made it possible to do away with the distributing head and avoid the consequences of the dispersing effect of the pressure gradient at the exit from it. In addition, in the annular clearance between the electrode 6 and the wall of the unit, in connection with the increase in flow velocity in this zone, the coalescence of the drops under the effect of the electric field is supplemented by their consolidation under the effect of the velocity pulsations.

Table 6

(1) Показатели	(2) Блочные печи		(3) Деэмульсатор	
	NN-2,5	NN-6,3	UDO-2M	UDO-3
(4) Производительность по сырью при нагреве па 40° C и обводненности 30%, т/сут	3000	8000	1600	3000
(5) Теплопроизводительность, млн. ккал/ч	2,5	6,3	1,5	3,5
(6) Масса, т	27,2	59,0	54,9	56,1
(7) Заводская стоимость, тыс. руб.	27,7	35,2	48,3	46,9

Key: (1) Indexes
(2) Modular furnaces
(3) Demulsifier
(4) Output capacity with respect to crude oil when heating to 40° C and with water content of 30 percent, tons/day
(5) Thermal output, millions of kcal/hour
(6) Mass, tons
(7) Factory cost, thousands of rubles

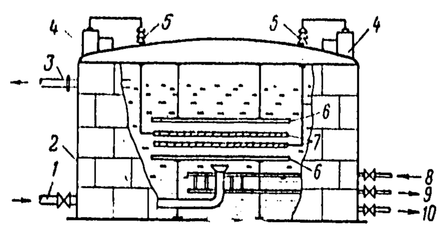

Figure 41. Nikodimesku Electrodehydrator Equipped at the Tank Base: 1--Oil input; 2--Tank; 3--Oil output; 4--Transformer; 5--Insulator; 6--Additional electrodes and solid baffle; 7--Electrodes; 8, 9--Input and output coils of the steam heater; 10--Water discharge.

The electrodehydrators in the United States were initially used only for desalination of the oil at the plants. The output capacity of one unit varied from several hundreds to 2500 m^3/day. The residual salt content in a number of cases reached 1 mg/liter. Then the devices began to be used for dehydration in the fields. Their output capacity was from 167 to 16,700 m^3/day with a residual water content to 0.5 percent.

Depending on the output capacity, the units have dimensions from 1.8 meters in diameter and 3.6 meters in length to 3.6 meters in diameter and 24.4 meters in length. The electric power consumption during dehydration depends on the conductivity of the emulsion. Usually for processing of the least conducting emulsions, 3.0 kilowatts are required for each 1,000 m^3/day of output capacity of the unit. On the average the cost of treating the oil on the Petreko electrodehydrators is about 1.12 cents/m^3 of dehydrated oil.

The oil is present in the unit for 20 minutes. The cost of the electrodehydrators is from 6 to 24 dollars/m^3 of daily output capacity, and it depends on the parameters of the oil. The large units are more economical when treating heavy oil. Thus, the Petreko unit on Lake Maracaibo in Venezuela removes water from the oil treated with demulsifier at the natural flow temperature (47° C). For dimensions of the unit of 3 meters x 6.2 meters, a volume of 43 m^3 and an output capacity of 2,000 m^3/day (730,000 m^3/year), the water content in the oil drops from 50 to 0.3 percent. The electrodehydrators 3.7 x 12 meters in size, depending on the density of the oil, ensure an output capacity from 830 to 1240 m^3/day. The units in a variable electric field develop an output capacity of 15,200 m^3/day ($\rho = 0.87$) and 11,450 m^3/day ($\rho = 0.9$). With a length of the unit of 10 meters and about 40 percent water content in the oil, the designed output capacity is 3.3 million m^3/year with a heating temperature of 37° C. The demulsifiers of different type are developed by many companies. The electrodehydrators developed by the BSB company (for stable emulsions) have the following characteristics.

	Type I	Type II		Type I	Type II
Type of demulsifier	Horizontal		Output capacity:		
Dimensions, m:			with respect to		
Diameter	1.8	3.0	liquid, m^3/day	167	5,300
Length	3.6	15.0	with respect to		
Pressure, kg-force/cm^2	3.25	1.5	oil, m^3/day	67	3,300
			with respect to gas, thousands of m^3/day	100	20,000

The Petrolight Company also manufactures chemical electrodehydrators, the cost of which, depending on their output capacity, can be determined by the data presented below:

Output capacity, thousands of m^3/year	150	300	600	900	1200	1500	1800	2100
Cost of equipment, thousands of dollars	10	15	20	24	30	35	36	36

The electrostatic horizontal demulsifiers built by the NATCO Company calculated for dehydration of oil are beginning to be widely used. The primary advantage of these units is that the dehydration process can be realized at a lower temperature than when using the ordinary type dehydrators, as a result of which the fuel gas is saved, the oil composition is improved, the corrosion of the equipment and scale formation are reduced. At high oil temperature in the wells, the need for heating is in practice eliminated. The fire hazard of the objects is reduced, and the environmental protection is improved. The data on the dimensions and designed output capacity of the electrostatic demulsifiers built by the NATCO Company are presented in Table 7. The lower limit of their output capacity corresponds to treatment of high-density emulsions (0.966) not containing free water; the upper limit corresponds to the treatment of unstable emulsions of light oil (0.815) in the units with a high amount of free water. The purity of the released water is not guaranteed. The company produces electrostatic demulsifiers, the designed (advertised) output capacity of which reaches 12 million m^3/year (Figure 42). However, models confirming the operation of the demulsifiers with such high output capacity are in practice still unknown.

Table 7

(1) Размер корпуса (D×L), м	(2) Мощность нагревательных труб, 1000 ккал/ч	(3) Число жаровых труб с наружным диаметром, см	(4) Производительность			(8) Номинальная мощность трансформатора, кВА
			(5) нефть, тыс. м³/год	(6) вода, тыс. м³/год	(7) газ, тыс. м³/сут	
1,2 × 3,1	63	1—30,5	8,7—26,3	11,6—28,8	6—17	2
1,8 × 4,6	139	1—45,7	26,3—140	28,8—88	14—28	5
1,8 × 6,1	252	1—45,7			14—28	5
2,4 × 4,6	189	1—61,0	70—254	74,6—104	42—57	5
2,4 × 4,6	277	2—45,7			42—57	5
2,4 × 6,1	378	1—61,0		46—139	42—57	5
2,4 × 6,1	630	2—45,7	140—324		42—57	5
2,4 × 7,6	378	1—61,0			42—57	5
2,4 × 7,6	567	2—45,7	175—350		42—57	5
3,1 × 6,1	504	2—45,7			57—85	5
3,1 × 6,1	630	2—61,0	193—394	56—174	57—85	5
3,1 × 6,1	756	3—45,7			57—85	5
3,1 × 7,6	504	2—55,7			57—85	15
3,1 × 7,6	630	2—61,0	246—595	56—174	57—85	15
3,1 × 7,6	756	3—45,7			57—85	15
3,1 × 9,1	504	2—45,7			57—85	15
3,1 × 9,1	630	2—61,0	280—800	56—174	57—85	15
3,1 × 9,1	756	3—45,7			57—85	15
3,1 × 10,7	756	2—61,0	280—800	87—260	57—85	15
3,1 × 10,7	945	3—45,7			57—85	15
3,1 × 12,2	945	2—61,0		115—348	85—142	25
3,1 × 13,7	1260	2—61,0	490—900	145—434	85—142	25
3,1 × 15,2	1512	2—61,0		174—520	85—142	25

Key: (1) Size of housing (DxL), meters
(2) Capacity of the heating tubes, 1000 kcal/hour
(3) Number of ball tubes with outside diameter, cm
(4) Output capacity
(5) Oil, thousands of m^3/year
(6) Water, thousands of m^3/year
(7) Gas, thousands of m^3/year
(8) Rated transformer power, kilovolt-amperes

The electrostatic demulsfiers operate on 16,000 volt DC current with a strength of 0.2 amps. The output capacity of such demulsifiers is 15 to 20 percent higher than the capacity of the AC electrodehydrators, and they cost 2 to 3 percent less than the latter. The main part of the electrostatic coalescer --the basic element of the electrostatic demulsifier--is the transformer 6 with satured core. The unit has the property of transforming power from the feed line in accordance with the required load depending on the conductivity of the oil treated in each instance. If the load becomes too great, the transformer reduces it to the admissible level. The operation of the equipment in the self-adjustment mode excludes the problem of short-circuiting and the disconnection of the feed system by protection which can be common to it and the transformer.

Figure 43 shows the usual schematic for creating an electric field in an electrodehydrator and in an electrostatic demulsifier. The emulsion to be treated is fed to the AC field (see Figure 43) created between the electrodes 1-2. Inasmuch as the water in the lower part of the unit had a potential equal to ground potential, it also acts like an electrode 3. The emulsion flowing off the oil-water phase interface is first subjected to the effect of the variable field with low voltage gradient and the basic amount of the water settles out. After passage through the electrode to the emulsion goes into a higher voltage zone in which the basic amount of water remaining in the oil coalesces. In a large number of cases the oil undergoing treatment in this zone contains no more than 0.1 percent water.

Figure 43, b shows the circuit diagram for the new electrostatic demulsifier. The same transformer is used here, but there are two lines at the output leading through the rectifiers to the positive electrode 10 and the negative electrode 9 respectively. This creates an extraordinarily high DC voltage between the electrodes 9-10. In this equipment the oil-water phase interface has the same potential as ground, and it is a third electrode 3. The interaction with the electrodes 9-10 in this zone creates a variable field with low voltage gradient.

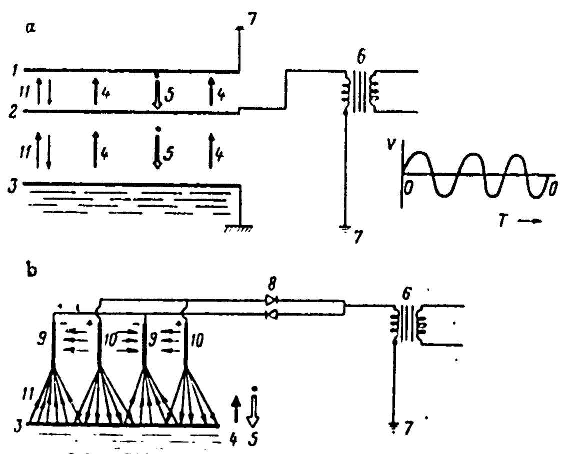

Figure 43. Schematic of the Arrangement of the Electrodes and the Directions of the Lines of Force in the Electrodehydrators of Different Structural Designs:
a--In the usual type equipment; b--In the electrostatic dehydrator; 1, 2, 3--Upper, middle, and lower electrodes; 4--Direction of motion of the emulsion; 5--Direction of motion of the enlarged drops of water; 6--Transformers; 7--Rounding; 8--Rectifiers; 9--Negative electrodes; 10--Positive electrodes; 11--Direction of the lines of force of the field.

In the operating process, only the positive part of the cycle comes to the electrode 10. If the oil between the electrodes contains a small amount of water, leaks of the charges from the electrodes 10 or 9 will not occur, and the voltage gradient will be quite high. If the water content in the oil increases, part of the charges will be lost, and the voltage gradient will drop automatically. Although the voltage gradient decreases and is restored 60 times a second, the direction remains constant, which creates a DC voltage field. With this design, we have the possibility of using a variable field in the zone of increased water content between the electrodes and the surface of the water and a DC voltage field with high parameters in the zone of reduced water content, which permits coalescence of the smallest drops. This combination of the electric fields improves the operation of the dehydration units which are highly superior with respect to efficiency to the traditional units. On the majority of units with moderate output capacity only "traces" of water remain in the oil.

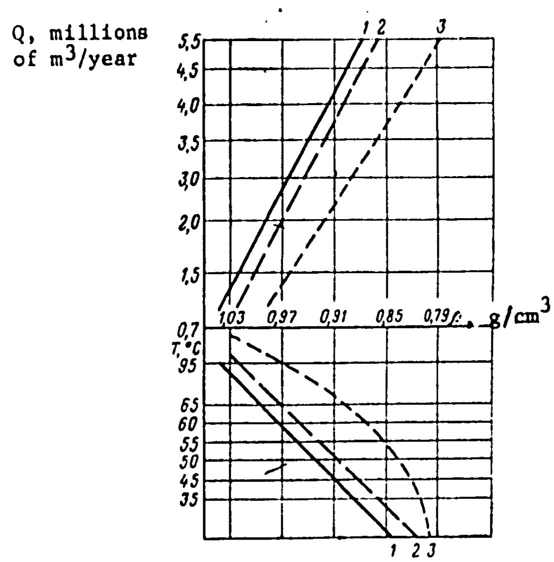

Figure 44. Output Capacity and Heating Temperature as Functions of the Oil Density:
1--Electrostatic dehydrators; 2--Usual type electrodehydrator; 3--Thermochemical settling tank.

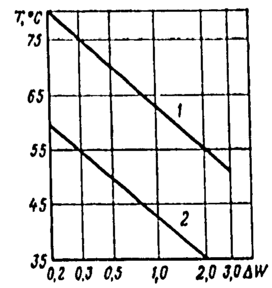

Figure 45. Residual Water Content in the Oil ΔW as a Function of the Heating Temperature for Oil with a Density of 0.8498: 1--Thermochemical settling tank; 2--Electrostatic dehydrator.

The study [202] points to the possibility of a significant increase in equipment productivity with the use of electrostatic dehydrators in comparison with thermochemical settling tanks or ordinary electrodehydrators.

In Figure 44 it is obvious that when treating oil with a density of 0.87 the theoretical load on the thermochemical unit 180 m^3 in volume exceeds 3 million m^3/year, the ordinary type electrodehydrator, 4.8 million m^3/year and the electrostatic dehydrator, 5.5 million m^3/year.

According to the data of R. V. Koggins [51], the degree of dehydration of the oil on the units utilizing an electrostatic field also increases by comparison with the ordinary thermochemical settling tank (see Figure 45). For equal heating temperature the degree of dehydration of the oil using the electrostatic dehydrator increases by 6-8 times.

If we compare the graphs in Figures 44 and 45 and try to find the relation between the output capacity of the units of different types and the degree of dehydration of the oil at equal temperatures, it turns out that for oil with a density of 0.849, the following relations will be valid.

For a heating temperature of 48° C, the residual water content in the oil during treatment in the thermochemical settling tank with an output capacity of 3.7 million m^3/year will be 3.0 percent. When treating the oil in the electrostatic demulsifier at the same temperature the residual water content will be 0.5 percent, and the output capacity will exceed 5 million m^3/year. Hence, it follows that for the given parameters of the oil treatment in the thermochemical settling tank, it is not ensured that conditioned dehydrated oil be obtained, or in the electrostatic dehydrator, desalinated. Obviously this turns out to be possible only when working with equipment with an output capacity appreciably less than the maximum values which are presented in the graph in Figure 44.

Table 8

Температура нагрева, °C	Производительность установки, %, при остаточном содержании воды в нефти	
	0,1%	0,2%
30	100	175
40	130	210
50	170	245
60	210	280
70	245	—

Key: (1) Heating temperature, °C
(2) Output capacity of the unit, %, for a residual water content in the oil of

Note. The output capacity of the unit at T = 30° C and a residual water content in the oil of 0.1 percent is taken as 100 percent.

Table 9

Плотность нефти	Количество товарной нефти, мас. %, при температуре нагрева, °C	
	32	82
0,809	94	91
0,873	97	96
0,913	98	98

Key: (1) Oil density
(2) Amount of commercial oil, mass percent, at a heating temperature of, °C

The output capacity of the units essentially depends on the heating temperature and the area of the electrodes. Table 8 gives the data on the increase in output capacity of the electrostatic dehydrators as a function of the heating temperature.

In the electrostatic demulsifiers the oil can be treated at a temperature of 8 to 15° C, which will permit a significant increase in the output of commercial oil. Table 9 shows the values calculated according to the data of reference [202] for the variation in the amount of commercial oil as a function of its density and heating temperature; hence, it is obvious that with an increase in temperature its losses can be significant, especially for light oil.

The operating expenditures on electric power depend on the size of the unit (the area of the electrodes) and the electrical conductivity of the oil. With an increase in electrical conductivity of the oil, the expenditures on the electric power increase. With an electric power cost of one cent per kilowatt, the expenditures on electric power when treating 1 m^3 of oil are on the average (for the average oil of the Gulf of Mexico), 1.2 cents.

On the whole, the advantages connected with the operation of the electrostatic dehydrators usually include the following:

High output capacity of the units;

A decrease in size of the process sites;

The possibility of carrying the process out at low temperature and with low consumption of fresh wash water;

Fuel savings;

A reduction in losses and an increase in volume of the commercial oil.

Without discussing the structural problems with the third level demulsifiers, let us indicate a number of decisive deficiencies characteristic of the equipment of this type as a result of which basic structural reworking of the equipment is necessary from the point of view of the modern concepts of the optimal conditions of breaking down emulsions:

Absence of mass exchange and stratifying section intensifying the demulsification process (and for the second level equipment, also the coalescing medium);

Failure to observe the principle of the optimal sequence of operations (heating, treatment with reagent, destruction of the protective shells, coalescence of the drops and stratification of the flow) and realization of them simultaneously with the same hydrodynamic unfavorable conditions of movement of the flow (more frequently, laminar);

Technologically inefficient combination of operations connected with heating the emulsion and its standing in one unit;

Realization of low distributed input of the emulsion through the layer of drainage water, in connection with which the output capacity of the unit is limited to the settling rate of the drops of stratal water suspended in the body of the oil directed opposite to the flow.

This results in low output capacity of the units, increased fire hazard, the necessity for shutting down the entire unit in case of a failure in any section, increased demand for monitoring and automation equipment and also regulating and valve fittings, and the necessity for using a high number of units at the high-output installations

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FUELS AND RELATED EQUIPMENT

TYUMENTRANSGAZ ASSOCIATION DURING 10TH FYP

Moscow GAZOVAYA PROMYSHLENNOST' SERIYA: EKONOMIKA GAZOVOY PROMYSHLENNOSTI in Russian No 1, Jan 79, pp 1-5

[Article by T. G. Zhuzhgova, Tyumantransgaz Production Association]

[Text]In accordance with the targets set in the "Main Directions for the Development of the National Economy of the USSR During 1976-1980", in 1980 it is planned to extract 435 billion m^3 of gas and increase gas extraction by 145.7 billion m^3. Of this total, growth in Tyumenskaya Oblast will amount to 120 billion m^3, in 1980 the entire annual increase planned for the nation will be attained from gas deposits in Tyumenskaya Oblast. During the current five year plan the volume of gas transported by the association will increase 2.6 fold, i.e. from 87.2 billion m^3 in the Ninth Five-Year Plan it will increase to 344.6 billion m^3, a growth of 257.4 billion m^3

While in 1975 consumers in the Urals and the center of the nation obtained 31.5 billion m^3 of Tyumen gas, in 1980 they will receive 82.6 billion m^3 through the association's gas pipelines, annual deliveries of gas will amount to 225.8 million m^3, (in 1975 the figure was 86 million m^3).

In order to transport this quantity of gas 2,964.2 kilometers of gas lines and 21 compressor facilities will be built (of this figure, 717 kilometers of lines and 6 facilities were introduced in 1976). Capital investments will total 1,916 million rubles and fixed capital valued at 1,072 million rubles (see Table) will be introduced. By the end of the five-year plan the value of fixed productive capital will amount to 3,404 million rubles, i.e. an increase of 2.7 fold in comparison with the corresponding data in 1975..

Table: Technical-Economic Indicators of Tyumentransgaz During the Tenth Five-Year Plan

	1975 Report	1976 Report	1977 Report	1978 Plan	1978 as percent of 1977
Commercial gas billion m^3	31.47	41.74	59.18	78.39	132.5
Value of fixed capital, million rubles	1,247.9	1,634.7	1,670.8	2,486.7	--
Capital investments, million rubles	463.7	319,5	310.1	202.5	65.2
Prime cost per 10,000 m^3 of gas, rubles	25.08	24.56	23.68	23.66	100.00
Profits, million rubles	16.27	33.20	26.42	32.32	122.00
Profitability, percent	1.3	2.03	1.3	1.29	99.2
Output/capital ratio, rubles	0.23	0.24	0.26	0.26	100.00
Ratio of Material Incentives Fund to Wages Fund, percent	11	10.1	8.76	9.50	108.5

The output/capital ratio of fixed ~~productive~~ capital will be reduced somewhat by the end of the five-year plan (from 0.23 to 0.21).

The output/capital ratio, characterizing the efficiency of fixed capital utilization, has especially great significance in pipeline transportation, since practical experience has shown that the introduction of compressor stations lags behind the introduction of gas lines and the time required to attain the planned productivity of gas lines is increased. In other words, the growth rate of fixed capital exceeds the growth rate of the amount of gas transported.

The development of the production association, similar to the transportation subsector, is being increasingly influenced by negative factors. The main ones are the increased average distance of gas transportation, and natural-climatic conditions. These factors are, to a considerable extent, causing deterioration of such indicators as prime cost and profitability.

By the end of the five-year plan prime cost for the association will increase by 24 percent, and the output/capital ratio will drop by 9 percent. The number of workers per 100 kilometers of gas, computed on a single line basis, continues to grow, although it is felt that it should decline. Insignificant increases in gas line distance have been accompanied by sizable growth in the number of GPA and the number of workers in gas transport is increasing primarily in the compressor service area: gas compressor station, KIP and A (Control and measurement equipment and automation), and EVC (Computers). For example, in 1976 717 kilometers of line were installed. The number of workers in gas transportation during this same period increased by 421; of which 144 were at the gas compressor stations, 59 at the KIP and A, sections, and 64 at the EVS section. There are 44 people directly engaged in servicing the line sections of the system, 10 percent of the total increase in personnel.

By the end of the five-year plan the number of workers will increase 2.9 fold and amount to 9,724 (in 1975 it was 3,327). Pipeline distance will increase by 66.7 percent -7,407 kilometers. By 1980 economic incentive funds will have practically doubled. In 1975 the FMP material incentives fund was 869,000 rubles, in 1980 it will be 1,683,100 rubles. The FMP is usually planned as a percentage of the FZP Wages fund and if examined from this perspective, everything is normal, i.e. the FMP is 10 percent of the FZP. However, if one looks at FMP payments per worker, then this indicator has deteriorated in 1975 it was 296 rubles, in 1976 - 281, and 1980 - 173. In order to solve the problems facing the nation in the Tenth Five-Year Plan it is necessary to carry out a complex of measures directed at revealing reserves, and improving the efficiency of fixed capital utilization and equipment operation reliability.

Specialists at the association have developed a five-year plan for improving the management system with these goals in mind.

The economic effect from implementing measures in this plan amounts to 202.7 million rubles. Implementing the measures will cost 159.5 million rubles.

The basic measures in the plan for improving the management system are:

1. Improvements in organizational structure - an economic effect of 3.8 million rubles.

2. Reductions in nonproductive expenditures and losses - an economic effect of 1.2 million rubles.

3. Increases in the reliability of equipment operation - an economic effect of 1.2 million rubles.

4. Measures for the acceleration of scientific-technical progress - an economic effect of 192.0 million rubles.

5. The mechanization and automation of management work. This section contains measures to provide workers in the management apparatus with management equipment, which includes computer hardware, equipment for preparing and copying documents, all types of communications. In 1975 the amount of equipment available for management work was worth 3,692 rubles per worker, and by the end of the five-year plan it will reach 7,100 rubles, i.e. a growth of 1.9 fold. This same section includes the introduction of automated management systems. The economic effect of measures for the mechanization and automation of management work is expected to reach 2.6 million rubles.

6. Reduction of the relative share of workers in the management apparatus by 22.3 percent in comparison to the norm and reductions in apparatus maintenance expenses through the introduction of a set of measures reflected in the management improvement plan. It is expected that the economic effect from this will amount to 1.9 million rubles.

In 1975 the number of workers in the management apparatus amounted 18.7 percent of the total, and in 1976 the figure was 17.9 percent, a reduction of 4.3 percent.

In the Tenth Five-Year Plan of efficiency and quality, the intensification of the conservation, rational and thrifty use of raw materials, other materials, and fuel and energy resources is very important.

Collectives at many enterprises in the sector have outlined and are implementing specific measures to reduce the material intensity of output, and conserve the use of materials, energy and other resources. In 1976 the Board of the Ministry of the Gas ordered an All-Union review of the efficiency of the use of materials, and fuel and energy resources at enterprises and organizations in the ministry.

The Tyumentransgaz Association, including all LPUMG, participated in the review. In 1976, during the course of the inspection, 531 suggestions were made, Of this number 491 were implemented and the economic effect from their introduction amounted to 171,500 rubles. Ninety-nine tons of turbine oil, 19,500 kilowatt hours of electrical energy and 6.6 million m^3 of gas were saved. The following measures were implemented:

Nadymskoye LPUMG Line production administration for main gas pipelines - additional feeding of hot air into the compressor shop through redesigning oil coolers. This ensures the reliability of the compressor station machinery hall heating systems and increases the temperature in the facility by 5-6 degrees.

Krasnotur'inskoye LPUMG - sold excess materials and equipment amounting to 26,000 rubles.

Kazymskoye LPUMG - heated production facilities at the field site through utilizing heat of reserve boilers. This reduced gas consumption for its own needs.

In order to develop the scientific and technical creativity of young people and to more extensively enlist young workers, specialists, engineers and technicians, a scientific-technical review of youth creativity was announced for 1977-1980.

A review commission of nine individuals chaired by the association's chief engineer has been created.

An integrated program for engaging young workers and specialists in scientific creativity has been developed.

In order to improve the standards of technical creativity of young collectives competition has been organized among young creative brigades to attain the best indicators for efficiency promotion. In 1977 the results showed that during the first stage of the review the better indicators were attained by the brigade of young innovators at the Long-Yuganskoye LPUMG, in which T. I. Zakharov, V. G. Nimchenko, and A.S. Vorob'yev.

The better works of young innovators are included in the collection "Rationalization Suggestions" published by the Tyumentrans- x gaz printing office and recommended for introduction at other LPUMG.

Thirty-nine young specialists underwent training at courses and institutes for improving qualifications in Moscow, Kiev, and Kaliningrad.

Innovators participated in the seminar: "Experience in the Utilization of Automated Management Systems at Enterprises in the Sector" conducted at the VDNKH Exhibit of the Achievements of the National Economy ; at a conference of young specialists in Tyumengazprom All Union Production Association, held under the slogan "Enthusiasm and Creativity of Youth in the Tenth Five-Year Plan", and in the Fourth Creative seminar in Urgench.

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FUELS AND RELATED EQUIPMENT

ECONOMIC EFFICIENCY OF NEWLY INTRODUCED NATURAL GAS DEPOSITS

Moscow GAZOVAYA PROMYSHLENNOST'. SERIYA: EKONOMIKA GAZOVOY PROMYSHLENNOSTI in Russian No 1, Jan 79 pp 20-21

[Article by S. V. Dubrova, Komi Branch VNIPI All Union Scientific Research and Planning Institute for the Gas Industry]

[Text] In compiling designs of OPE and developing gas deposits, the comparative efficiency of their operation is determined by comparing costs for the exploration, extraction, and transportation of gas with the closing costs at the site of its use (1). Using such comparisons, even very capital-intensive deposits are more efficient than coal extraction.

However, if one calculates the absolute efficiency of the gas extracting enterprise and the time required to recover capital investments in gas extraction, not every gas field's profits justify expenses for project development within the norm period. Thus, with respect to cost levels, the majority of small and medium deposits in the Timano-Pechora province of the Komi ASSR are lower than closing costs, but have low profitability or even losses. The time required to recover investments amounts to 8-27 years, with an average cost of 6 rubles per 1,000 m^3 of gas (see Table I)

In connection with work on the new system of economic incentives now being conducted, the profitability level indicator has great significance in evaluating the economic activity of gas enterprises. It is computed as the ratio of total profit to productive capital and shows the profit society obtains per ruble of productive resources expended. However, in the practical work of planning deposit development, this indicator is still not widely used. It permits relating the efficiency of capital investments in deposit development with the system of enterprise profit and loss indicators and gives consideration to real investment recovery periods for deposit development (1).

Table I. Indicators of the Efficiency of the Development of Promising Deposits in the Komi ASSR

Месторождения по районам провинции (1)	(2) приведенные затраты, руб./1000 м³				Эффект (7) от использования газа по сравнению с замыкающим топливом, руб./1000 м³	Рентабельность, % (8)	(9) минимальная необходимая отпускная цена для предприятия с учетом отчислений на ГРР, руб./1000 м³
	на добычу (3)	На ГРР и транспорт до Ухты (4)	на транспорт от Ухты до Центра страны (5)	итого (6)			
(10) Нарьян-Марский							
(10.1) Лаявожское	5,8	4,3	4,5	14,6	8,4	13	7,3
(10.2) Ванейвисское	6,4	4,3	4,5	15,2	7,8	11	7,9
(10.3) Василковское	7,5	4,3	4,5	16,3	6,7	8	9,0
(10.4) Кумжинское	9,1	4,3	4,5	17,9	5,1	5	10,6
(11) Верхне-Печорский							
(11.1) Рассохинское	9,2	6,1	4,5	19,8	3,2	4	10,7
(11.2) Пачгинское	9,3	6,1	4,5	19,9	3,1	4	10,8
(11.3) Курьинское	14,7	6,1	4,5	25,3	-2,3	-	16,2
(12) Средне-Печорский							
(12.1) Печорокожвинское	13,9	3,8	4,5	22,2	0,8	3	15,4
(12.2) Печорогородское	22,5	3,8	4,5	30,8	-7,8	-	24,0
(12.3) Западно-Соплясское	41,5	3,8	4,5	49,8	-26,8	-	43,0

Key:
1. Deposit by Region of Province
2. Calculated Costs, rubles per 1,000 m³
3. For extraction
4. For geological exploratory work and transportation to Ukhta
5. For transportation from Ukhta to Center
6. Total
7. Effect from the use of gas in comparison with closing cost fuel, rubles per 1,000³
8. Profitability
9. Minimal necessary transfer price for enterprise, including deductions for geological exploratory work. rubles per 1,000 m³

10. Nar'yan-Marskiy
 10.1. Layavozhskoye
 10.2 Vaneyvisskoye
 10.3. Vasilkovskoye
 10.4. Kumzhinskoye
11. Verkhne-Pechorskiy
 11.1. Rassokhinskoye
 11.2. Pachginskoye
 11.3. Kur'inskoye
12. Sredne-Pechorskiy
 12.1. Pechorokizhvinskoye
 12.2. Pechorogorodskoye
 12.3. Zapadno-Soplyaskoye

The profitability level involves many interacting factors which depend on initial reserves, well productivity, development conditions, gas extraction technology and processes, production organization, and others. It is related to the coefficient of the economic efficiency of deposit development, E, which is the relationship of profit to capital investment. If, as a result of the measures suggested, the coefficient of efficiency is lower than the norm (En) the expenditures are not justified within the sector pay off period. For example, if in industry En = 0.12, the production profitability level should not be less than 12 percent, i.e. the margins for the economically rational development of a deposit are determined by the conditions E is greater than or equal to 0.12, or T is less than or equal to 8.3 years.

As practical experience has indicated, at large, high production rate deposits the coefficient of efficiency is quite high, while at medium and small production rate deposits it is low. Small and capital intensive deposits will have coefficients of efficiency less than 0.12 (see Table I).

At the Timano-Pechora province several groups of promising deposits are distinguished by the level of prime costs:

Low cost hydrocarbon resources (2-3 rubles per 1,000 m^3) - Layavoznskoye, Vasilkovskoye, Vaneyvisskoye;

Medium cost (4-5 rubles per 1,000 m^3) - Kur'inskoye, Rassokhinskoye, Pechginskoye;

High cost (6-7 rubles per 1,000 m^3) - Kur'inskoye, Pechorokozhvinskoye';

Very high cost (9-15 rubles per 1,000 m^3) - Pechorogorodskoye, Zapadno-Soplyanskoye

The efficiency of developing the majority of these deposits is beyond the limits of the cut off for capital investment recovery. However, the enterprise price for gas (6 rubles per 1,000 m^3) does not give an objective evaluation of the absolute efficiency. Since part of the gas field profits are used by the enterprise to transport gas, some authors (1,2) recommend calculating the coefficient of capital investment efficiency not within the framework of a single deposit, but from the perspective of the gas sector (Eo). Table I shows the coefficients of efficiency for the developing of deposits with consideration given to costs and profits for transportation enterprises in the sales of gas to consumers in the Komi ASSR and the Center of the nation. The total efficiency of capital investments calculated in this way is higher than for a gas field, however, Eo is greater than or equal to En only for three deposits in the province.

In connection with the nation's growing scarcity of gas, especially in the European sections, one should attempt to find conditions under which developing the low production rate deposits would be economically justifiable. A recovery period within the norm can be attained through increasing well flow and reducing the cost of well installation and field development. However, this is not now always done.

Changes in existing enterprise transfer prices for gas could also help improve profitability. The minimal transfer price, P for obtaining the necessary profit and compensating for enterprise expenses is found by the recovery formula.

$$T = \frac{K}{(Q_r(P - s)}$$

$$P = \frac{K}{Q_r \cdot T} + S = k_{yd} \cdot E + S_d$$

Where: K - Total capital investments for the development of the deposit

k_{ud} - Relative capital investments

T - Norm pay off period (8.3 years)

Q_g - Annual gas extraction

S - Prime cost for the extraction of 1,000 m^3 of gas.

That is, product transfer price should, at a minimum be equal to calculated costs and differentiated for enterprises with regard to their size. In addition, it is necessary to increase it by 1.5 rubles per 1,000 m^3 in order to compensate for costs for geological exploratory work (GRR). This means that if gas prices were increased to 8 rubles per 1,000 m^3, the development of the Layavozhskoye and Vaneyvisskoye deposits would become feasible, if increased to 11 rubles per 1,000 m^3, then the development of the Kumzhinskoye, Rassokhinskoye, Pachginskoye deposits, etc. would become feasible (see Table I).

To the extent that the marginal value of prices are closing costs, reflecting the level of socially necessary costs to satisfy requirements in cases of lack of output (I), the problem of the possibility of increasing enterprise gas transfer prices should be solved on the basis of the difference between costs for closing output in regions of its consumption and calculated costs for the exploration, extraction, and transportation of gas to consumers.

Calculated costs for geological exploration work and transportation of gas from the city of Ukhta and then on to the Center of the nation are calculated for four arbitrary regions of the Komi ASSR. The difference between closing cost and these costs determines the maximum allowable calculated costs for gas extraction in the region of the deposits (Table 2), or the limiting maximum price for gas sales.

Table 2. Calculated Costs for Gas Extracting Regions of the Timano-Pechorskaya Province

Costs	Nar-yan Marskoy	Verkhne-Pechorskiy	Credne-Pechorskiy	North east
Calculated Costs				
For geological exploratory work	3.4	5.7	3.8	6.5
For transportation to Ukhta	0.9	0.4	-	0.5
For mainline transportation from Ukhta to the Center	4.5	4.5	4.5	4.5
Maximum allowable calculated costs for gas extraction	14.2	12.4	14.7	11.5
Closing costs	23.0	23.0	23.0	23.0

In comparing the calculated minimal necessary price for the enterprise (see Table 1) with the marginal cut off for calculated extraction costs by region (Table 2) we come to the conclusion that these prices cannot be set for all deposits in the province. For the last four (see Table 1) the necessary prices exceed the maximum allowable costs (or prices) for gas extraction. Consequently, one can see that their development is not now advisable.

In solving the problem of deposit development efficiency, it is not sufficient to estimate the national economic efficiency only through determining comparative efficiency. It is necessary to simultaneously determine the absolute efficiency of capital investments in development, comparing the coefficient of efficiency (or profitability)with the normed efficiency coefficient of the sector.

For deposits where E is less than or equal to E_n one should look at conditions under which their development will be sufficiently profitable. This includes the possibility of changing transfer prices for field output. If this requires setting a transfer price higher than the allowable cost for gas extraction (closing) in the region of consumption minus costs for geological exploratory work and transportation, it is not economically advisable to develop the deposit.

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FUELS AND RELATED EQUIPMENT

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PRIME COST OF GAS DEPOSITS

Moscow GAZOVAYA PROMYSHLENNOST'. SERIYA: EKONOMIKA GAZOVOY PROMYSHLENNOSTI in Russian No 1, Jan 79, pp 25-29

[Article by N. M. Soshnin (Sevkavniigaz, G.S.Urison (VNIIgaz)]

[Text] In accordance with the presently existing organizational structure, the majority of gas field administrations (GPU) for gas extraction, or administrations for gas extraction and transportation (UDTG) include several gas deposits. For example, in 1976 the Kuban'gazprom [Kuban gas industry Association] had developed 25 gas and gas condensate deposits, including the Krasnodarskoye UDTG - 10, the Kanevskoye GPU - 12, and the Maykopskoye DGT - 3. In existing report procedures expenditures are considered for the GPU as a whole without distribution to individual deposits. The GPU's individual deposits differ significantly with regard to their geological and technical characteristics, and correspondingly their economic characteristics. In order to analyze economic activity, determine deposit development efficiency, and ascertain basic directions for the improvement of economic indicators it is necessary to define costs for each deposit under examination. Such studies are being made by workers at scientific research organizations or gas extracting enterprises. However, the methodology for allocating costs has not yet been developed and studies use different methods for allocating overall costs between individual deposits. A simplified method for determining costs for individual deposits is suggested.

In accordance with existing instructions, the planning, accounting and calculation of gas and condensate extraction prime costs is carried out by the following computational class of expenditure:

Auxiliary materials (reagents)
Basic, supplementary wages and deductions for social of productive workers;

Expenditures for production preparation and development;
Well amortization;
Expenditures for the maintenance and operation of field equipment;
Expenditures for preparing (compressing) gas;
Expenditures for the intr field transportation of condensate;
Shop expenditures;
General field expenditures;
Other field expenditures;
Non-production expenditures.

Some of these classes - wages, amortization of wells, costs of gas preparation - can be calculated directly for each deposit. Expenditures for auxiliary materials can also be determined by calculation: by multiplying the quantity of gas extracted at deposits and the relative expenditure of auxiliary materials. Expenditures for intrafield transportation of condensate are also calculated directly if they are spent ior one field. If, however, condensate transportation is for a group of deposits, costs for individual deposits are determined proportionally to the amount of condensate transported. In calculating gas extraction prime cost, well amortization has its own section. The amortization of other fixed capital is included under the expenditures for maintenance and operation of field equipment, and under shop and general field expenditures. However, in the "Estimate of production costs", the total sum of amortization is calculated. By subtracting well amortization from it one can determine the amortization of other fixed capital for GPU. The resulting figure is broken down into individual deposits proportionally to the value of fixed capital (without wells) of each deposit.

Expenditures for all other classes of costs - shop, general field, for the maintenance and operation of field equipment (minus amortization) are all comprehensive. They should be distributed among individual deposits. The magnitude of these costs depends upon a number of factors, however, the most important are the number of operating wells and the volume of gas produced. To determine these expenditures for individual deposits the following formula can be used:

$$K_o = \frac{\frac{p_i}{p} + \frac{Q_i}{q}}{2}$$

Where:

K_o - Is a coefficient reflecting thesshare of wells and gas extraction of individual deposits in the total amount of wells and gas extraction in the administration, in shares of units

p_i and p - Operating wells by deposit and administration

q_i and q - Gas and econdensate extraction by deposit and GPU

Table 1 presents the calculation of gas extraction prime costs for the Kuban'gazprom Association and individual gas field administrations, Table 2 gives the structure of operating expenditures calculated according to the suggested classification.

Table 1. Calculation of the Prime Cost of Gas and Condensate by Administration of the Kuban'gazprom Association for 1976

Статьи затрат (1)	Объединение (2)	В том числе:		
		Краснодарское УДТГ (3)	Каневское ГПУ (4)	Майкопское УДТГ (5)
(6) Вспомогательные материалы (реагенты)	440	148	169	123
(7) Основная и дополнительная заработная плата производственных рабочих, включая отчисления на социальное страхование	1165	266	683	216
(8) Расходы на подготовку и освоение производства	23	8	8	7
(9) Амортизация скважин	11813	5684	3303	2826
(10) Расходы на содержание и эксплуатацию промыслового оборудования	11408	3558	6210	1640
(11) Расходы на внутрипромысловый транспорт конденсата	132	-	85	47
(12) Общепромысловые расходы	4046	1591	1654	801
(13) Прочие промысловые расходы	19	8	7	4
Total	29046	11263	12119	5664

Note: Prime cost calculated without compensating for GRR costs.

Key:

1. Class of cost
2. Association
3. Krasnodarskoye
4. Kanevskoye GPU
5. Maykopskoye
6. Auxiliary materials (reagents)
7. Basic and supplementary wages of production workers including deductions for social insurance
8. Expenditures for production preparation and development
9. Well amortization
10. Expenditures for the maintenance and operation of field equipment
11. Expenditures for intrafield transportation of condensate
12. General field expenditures
13. Other field expenditures

Table 2. Breakdown of Operating Expenditures for Gas Extraction Following Recommended Methodology (Percent of Total)

Class of Expenditure	Administration: Krasnodarskoye UDTG	Kanevskoye GPU	Maykopskoye UDTG
Auxiliary materials (reagents)	1.3	1.4	2.2
Basic and supplementary wages of production workers, including deductions for social insurance	2.4	5.6	3.8
Well amortization	50.5	27.3	49.9
Amortization of other fixed capital	16.9	29.8	21.2
Other expenditures	28.9	35.9	22.9
Total	100.0	100.0	100.0

As can be seen from tables 1 and 2 the prime cost structure is dominated by expenditures for well amortization, maintenance and operation of field equipment (the latter section includes expenditures for installing low temperature separation equipment and gas collection networks). Outlays for these two classes amount to about 80 percent of operating expenses.

Using this methodology, calculations were made of gas extraction prime costs in the largest deposits in the Kuban'gazprom Association (Table 3)

It is obvious from Table 3 that gas extraction prime costs for individual deposits differ significantly from the average for the GPU. Thus, gas extraction prime cost at the Starominskoye deposit, was 3.3 fold and for the Leningradskoye 4.6 fold higher than the average prime cost for the Kanevskoye GPU, while at the Kanevskoye and Kushchevskoye deposits the figures were 1.8 - 1.9 fold lower.

Thus, the suggested method for allocating operating expenditures permits calculating costs for the development of individual deposits and determining the economic economic efficiency, as well as setting the most important directions for the improvement of gas field administration management activity.

Table 3. Calculation of the Prime Cost of Gas Extraction for the Kuban'gazprom Association in 1976, Thousands of Rubles.

Месторождения по управлениям (1)	Годовые эксплуатационные расходы, всего x) (2)	(3) В том числе: вспомогательные материалы (4)	заработная плата (5)	амортизация скважин (6)	амортизация прочих основных фондов (7)	прочие затраты (8)	Себестоимость добычи газа, руб/1000 м³ (9)
(10) Каневское ГПУ, всего	12119	169	683	5503	5625	4839	5,27
(11) в том числе по месторождениям:							
(12) Каневское	2548	66	138	646	430,0	1267	1,80
(13) Ленинградское	1328	4	125	325	443,0	221	15,06
(14) Челбасское	873	9	89	345	239	191	4,60
(15) Староминское	1428	6	97	680	422	228	10,79
(16) Кущевское	1418	37	82	503	328	668	1,75
(17) Крыловское	1979	35	112	622	657	553	2,59
(18) Краснодарское УДТГ, всего	11263	148	266	5684	1900	3265	10,02
(19) в том числе по месторождениям:							
(20) Березанское	3244	46	91	1475	571	1061	9,36
(21) Сердюковское	801	11	20	559	107	504	9,47
(22) Некрасовское	2631	48	87	1250	434	812	7,17
(23) Майкопское УДТГ, всего	5664	123	216	2826	1197	1302	13,10
(24) в том числе по Майкопскому месторождению	4341	113	184	2065	825	1154	10,91
Total Итого	29046	430	1133	11813	6550	8738	5,37

x) Includes expenditures for gas and condensate extraction

Key:
1. Deposit (by administration)
2. Annual operating expenditures[x)] total
3. Including
4. Auxiliary materials
5. Wages
6. Well amortization
7. Amortization of other fixed capital
8. Other costs
9. Prime cost of gas extraction, rubles per 1,000 m^3
10. Kanevskoye GPU total
11. Including the following deposits
12. Kanevskoye
13. Leningradskoye
14. Chelbasskoye
15. Starominskoye
16. Kushchevskoye
17. Krylovskoye
18. Krasnodarskoye UDTG, total
19. Including the following deposits
20. Berezanskoye
21. Serdyukovskoye
22. Nekrasovskoye
23. Maykopskoye UDTG, total
24. Including the Maykopskoye deposit

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END